DECEMBER 1957

THE WELDING JOURNAL

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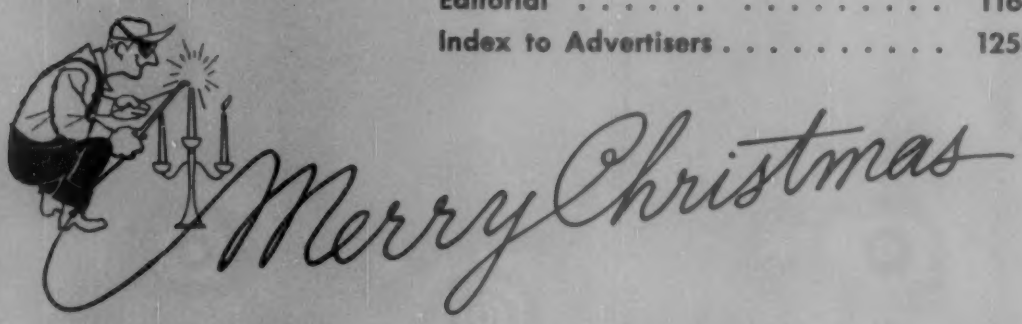

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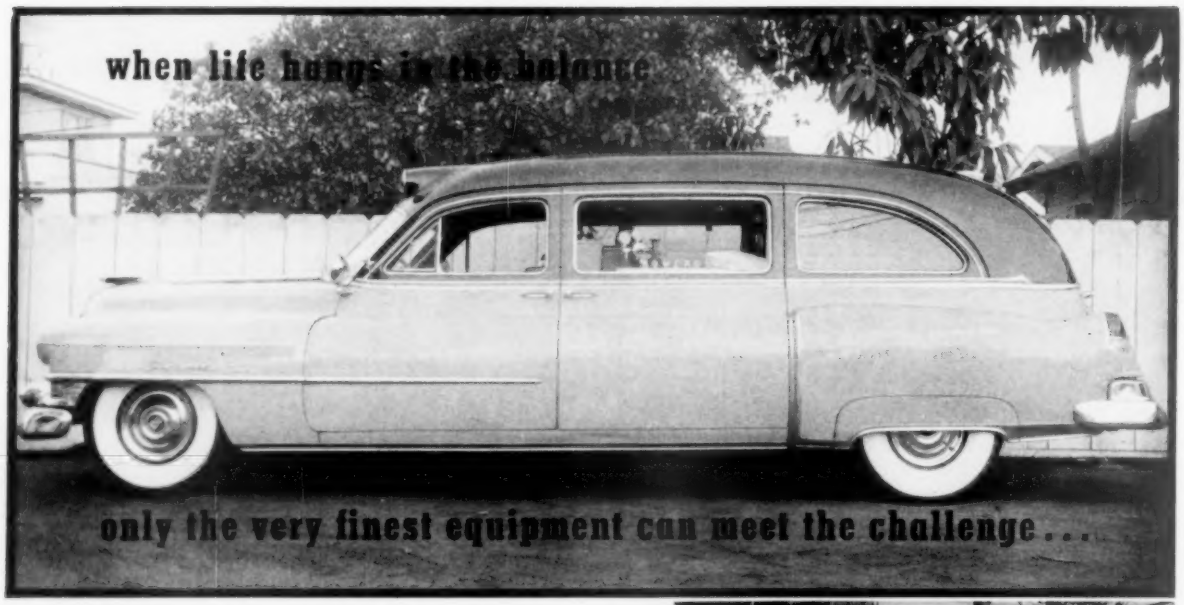

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M. M. McCall

THE
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JOURNAL

EDITORIAL

Marguerite M. Kelly

For thirty years Marguerite M. Kelly served the AMERICAN WELDING SOCIETY faithfully, unselfishly and with distinction—carefully guiding the newly formed organization through its formative years; shrewdly and skillfully compromising the rivalries which existed between the major elements of the young but rapidly expanding industry; tactfully cooperating with and implementing the policies of the 23 national presidents and six national treasurers with whom she was associated.

Miss Kelly received her business training at Columbia University and then served as a member of a group from the University appointed to assist the Italian Aviation Commission that came to the United States during the first World War to inspect American methods and equipment. Later she accepted a position as Secretary to Dr. Comfort A. Adams who was then President of the American Institute of Electrical Engineers and Chairman of the Welding Committee, Emergency Fleet Corp.

When the AMERICAN WELDING SOCIETY was organized in 1919 with Dr. Adams elected as its first president, Miss Kelly became a staff member serving as Assistant Secretary from 1919 to 1920; Acting Secretary from 1920 to 1922; and Secretary from 1922 to 1949. During these years Miss Kelly developed and improved procedures for Headquarter and Section operation; assisted in the organization of Sections; and acted as Secretary to the Board of Directors and to many Standing Committees including the Convention Committee.

Under her able guidance, the annual budget of the SOCIETY grew from a few thousand dollars to well over a quarter of a million dollars, and membership attained a World War total in excess of 8000, reflecting the great increase in scope and breadth of SOCIETY activities.

In 1949, after so many years of continuous and arduous service, Miss Kelly retired from full-time activity and was named Secretary Emeritus. Since then and until her death on October 22, 1957 she maintained her keen interest in affairs of the SOCIETY and never failed to make available her wealth of experience.

Probably no one has contributed more to the success of the AMERICAN WELDING SOCIETY than Marguerite M. Kelly.

Fred L. Plummer
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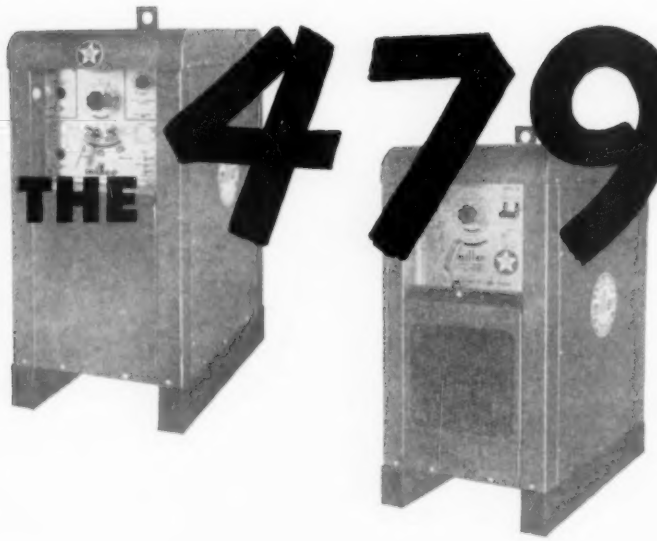

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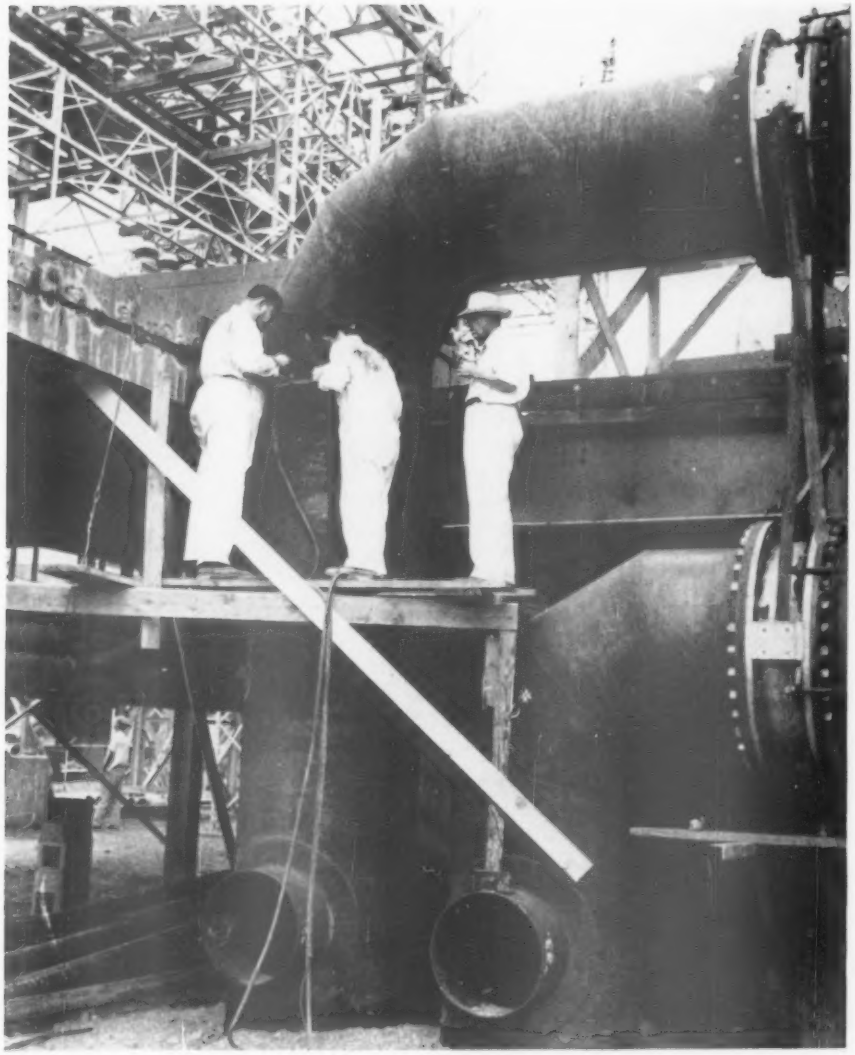


Fig. 1 Outside view of main water-supply line to a new utility generating station

LEAK PREVENTION—
THROUGH IN-PROCESS LEAK DETECTION

Use of fluorescent penetrants and fluorescent additives for leak detection is discussed by author

BY RICHARD P. TURNER

If leak detection is mentioned to a tank or vessel manufacturer, the first test method that he generally thinks of is a pressure test. A very natural reaction for two reasons. The first is that practically all tanks or vessels designed to meet various code requirements must be fill or pressure tested before acceptance. The second is that from the start of time, vessels or containers of all types, have been tested in this manner.—Fill it up and see if it leaks.

How many other industries have such a universally accepted specification? Frequently unwritten, yet so well recognized by all concerned as an essential requirement, that controversy regarding its neces-

R. P. Turner is associated with Magnaflux Corp., Los Angeles, Calif.

sity is simply unheard of. Tanks or vessels are generally purchased to contain fluids or gases. Naturally, some sort of proof test or simulated operation test is indicated.

For the user, concerned only with whether or not the finished container or vessel leaks, pressure testing may be the answer. For the manufacturer, however, concerned with production cost as well as final quality, it is not.

Final Inspection Costly

In any industry, an inspection technique or testing method, used only as a means of determining final quality, by inspection of the finished product, is an added production expense. The welding industry producing tanks or vessels is certainly no exception. The very nature of a pressure test generally restricts its use to the finished tank. Leaks are detected only after fabrication has been completed. Re-working and re-testing at this stage of production are time consuming and expensive.

A manufacturer can attain the greatest degree of profit only if there is complete assurance of the integrity or quality of each component, sub-assembly, or rough part as received. As an example, a TV tube costing $11.00 can be rendered unsaleable because a seam in a small wire, costing only a few pennies, permits air to leak into the vacuum.

Is there a better time for a tank manufacturer to determine quality of a weld than immediately after the weld bead has cooled? If inspection at this stage in production is fast and accurate, it naturally follows that re-work and production costs would be kept to a minimum.

In-Process Inspection Saves

The purpose of this paper is to discuss the rapidly expanding use of fluorescent penetrants and fluorescent additives for leak detection. Properly used, these materials can determine quality of the finished tank, but more important, actually assure quality through in-process leak detection (Figs. 1 and 2).

Fluorescence may be defined as the ability of a material to accept invisible light energy and transform it to a highly-visible energy. All petroleum products fluoresce to a certain degree. A fluorescent penetrant is an oil base material compounded for penetrating ability and fluorescent brilliance. A fluorescent additive is a material, usually a dry powder, which is added to a liquid to increase or give it fluorescence. These materials, when exposed to a black light emitting a wave length of approximately 3650 angstrom units, fluoresce brilliantly. Color may be yellow, yellow green or red depending on the material used. For the detection of fine leaks, a high intensity black light is essential. A minimum of 90–100-ft candles on the work should be used.

Fluorescent materials are used in two ways for leak detection. Penetrants are used to check welds for soundness during vessel fabrication, and additives are used to make pressure tests more positive.

Fig. 2 Inspector using black light to detect leaks in welds before high-pressure hydrostatic test. Penetrant is applied by brush to outside of weld—inspection is done on inside

Fig. 3 Spraying fluorescent penetrant on weld to be leak tested

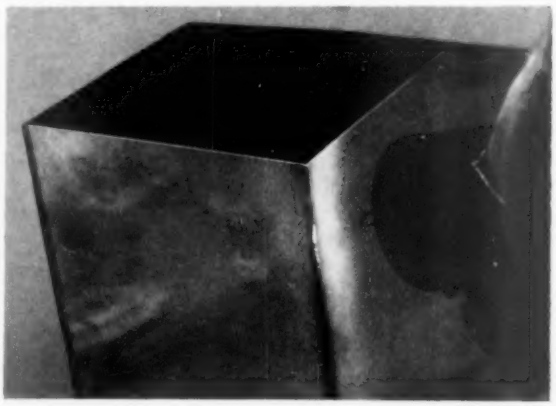


Fig. 4 Leak shows as brilliant fluorescent indication under black light

Fluorescent Penetrant for Leak Detection

In using penetrant, the welder or inspector merely paints, brushes, or sprays the penetrant on one side of the weld. Small pressurized cans are very useful for spray applications (Fig. 3). After a suitable penetration time during which the penetrant travels through any minute leak passages in the weld, the opposite side is scanned under black light (Fig. 4). This penetration time depends on thickness of the weld and can vary from 2 to 5 min to an hour or more. Even extremely-minute leaks are readily visible as brilliant fluorescent spots. During the penetration time, the welder or inspector is free to continue fabrication or other work on the vessel. For the longer penetration time, usually required with heavier welds, it is best to make a second application of penetrant over the first. Heavier welds mean longer leak passages, and the additional supply of penetrant increases the speed and efficiency of the test. If leaks are discovered, their exact location is pinpointed for the welder, and repairs are made before the tank or section leaves the weld shop. Penetrant should always be applied to the repaired area to check the soundness of the repair.

Variety of Welded Products Tested

This technique is being used very successfully by manufacturers of vacuum vessels, home appliances, coffee urns, kitchen and diner equipment, oil, gas and syrup cans, food processing equipment for the dairy, ice cream and other industries, and by manufacturers of large and small tanks for practically every use. Why this industry-wide acceptance and rapidly expanding useage? Simply because these manufacturers, by using fluorescent penetrants for in-process leak detection, not only guarantee quality but actually reduce their production costs. Leaks are discovered early in manufacturing when re-work is more economical, and the finished product, whether pressure tested or not, does not leak. Let's see how this works in actual practice.

Welder Tests Own Welds

During World War II, a large manufacturer of circuit breakers had to meet a production schedule of 19 cases per week. A final pressure test was specified. Due to the complicated nature of the case, setup time for pressure test was extensive. Although welders were top-notch, it took so long to test, locate the leaks, repair and re-test—occasionally many times per case—that maximum production was far below schedule. This company experimented with, and then adopted, fluorescent penetrant as a means of controlling quality. Each welder was furnished a black light, a small can of penetrant, and a paint brush. (Although not this specific application—a similar one is shown in Figs. 5 and 6). As a weld was completed, it was leak tested then and there by the welder with no lost production time. Although final pressure test was still required,

Fig. 5 Welder applies penetrant, and...

Fig. 6 ...inspects own weld for leak

cases would pass on the first test. Repair at that stage of production, and the corresponding re-setup and re-testing time were practically eliminated. The first week that this fluorescent-penetrant inspection technique was in use, the company was able to exceed their production requirement.

Testing Open Tanks

In another case, the manufacturer of stainless-steel tanks and vessels for the dairy industry would either fill test or pressure test with tap water. These tanks would average somewhere between 400 and 1000-gal capacity. In some cases up to 90 lb of air was used on a water-filled tank to make leak detection more positive. Any leakage at this final inspection meant draining of the tank, repairing, and re-filling for another test. In 1950, this company started to use a fluorescent penetrant for leak detection and has relied on it ever since. On open tanks, the penetrant is applied by brush to the inside of all weld seams. Twenty minutes later, the outside of the weld is scanned under black light. Repairs are made immediately and re-checked in an identical manner.

Testing Closed Tanks

On closed tanks, rather than using a fill or pressure test for final inspection, they now pour in a small quantity of penetrant and slosh it around so as to coat all welds. Inspection is performed the same as on open tanks. If leaks are detected, the tank is positioned so that the penetrant is on the opposite side while repair work is proceeding. The repaired area is then leak tested in the same manner. Following completion of all inspection and necessary repair work, the penetrant is drained out and re-used.

Removal Following Inspection

You may have a question about complete removal of these penetrant materials following inspection. Even with food processing equipment of this nature, this company reports that by using a special detergent for final cleaning, they experience no trouble in completely removing all traces of the penetrant from the inside of the vessel. The savings in this case are quite obvious. Painting welds with fluorescent penetrant versus filling a 400 to 1000-gal tank with water, checking for leaks, draining, re-filling, and re-inspecting.

Inspecting Automatic Welds

Appliance manufacturers, both here in the United States and in Canada, make extensive use of fluorescent-penetrant leak detection on various welded subassemblies. Refrigerator liners are an example. Before using fluorescent penetrant, many defective seam welds in the liners were not discovered until after pickling, enameling, and firing. Discovery at this point, of course, was too late. The liner was worthless other than for sale as scrap. Fluorescent penetrant was first tried as a brush-on technique. Penetrant on one side of the seam immediately after welding and inspection of the other side twenty minutes later. The results were excellent. Leakers were found, repaired, and re-inspected before further processing. Savings in scrap alone in one plant amounted to several thousand dollars the first year this process was adopted. Penetrant application, by the way, is no longer a brush-on method. A continuous roll-on technique immediately after welding has been adopted.

Vacuum Vessels

Vacuum vessels have always posed a rather special problem. Providing suitable test stands are used, any leakage is easily detected. Finding the leak, however, may be an entirely different matter.

One of the large manufacturers of practically all types of tanks in the inter-mountain area is The Lang Co. Inc. of Salt Lake City, Utah. In 1953, they had six or seven stainless-steel vacuum vessels approximately 3 ft in diam and 4 or 5 ft long to fabricate for one of their customers. Although they had never before used any of these fluorescent penetrant materials for leak detection, they tried it on this job. During fabrication, as soon as two stainless-steel plates were welded together, the inspector leak tested the seam. After penetrant was brushed on one side, there was a short penetration time during which normal production work continued, followed by black light scanning of the opposite side. Leaks were immediately repaired and the area re-tested. In no case was it necessary to move the sub-assembly out of the fabrication area. The thoroughness of their inspection was apparent in that each and every vessel was on the test stand only once. Not one leak was detected in the final acceptance test. Ever since that date, this company has continued to use fluorescent penetrants for in-process leak detection on all similar vessels with the same satisfactory results.

Fluorescent Additives Used with Kerosene on LPG Tanks

The vacuum vessel, as mentioned before, is only one of many types produced by this same manufacturer. Liquid petroleum gas (L.P.G.) tanks are a production item. They are also a highly competitive item. Production costs are always important to a manufacturer, but in this case product performance and customer satisfaction were more important. Even with a production of up to 50 tanks per day a possible one or two leakers returned from the field per month was too many. One or two too many, to be exact. Could a similar type of fluorescent inspection be used to make their final pressure test more positive?

All L.P.G. tanks are tested with kerosene at 400 lb per sq in. A 2000-gal kerosene reservoir is maintained and the material used over and over. Although considerably more expensive than water, the kerosene was, they felt, more desirable as a testing medium. Even a minute amount of water in a L.P.G. tank in cold weather means immediate trouble.

The use of kerosene eliminated this possibility, but occasionally, a leaker went undetected by this method, and got into the field.

There is no question but that the kerosene in a tank

being tested at 400 lb per sq in. will leak. With an extremely minute leak, however, the wet area indication is practically invisible. In any test method, sensitivity of the inspection material that is used doesn't mean a thing if you can't see the defect indications produced. To improve their pressure testing technique, this company added a fluorescent additive to the kerosene to increase the visibility of leak indications. Now, during pressure test, instead of visually examining all welds under strong white light, the inspector merely goes over them with a black light. Even the smallest leak is indicated by a brilliant fluorescent dot. Have the results been worthwhile? This technique was installed in early 1954, and since that date they report not one leaker has reached the field. Only two minor changes in their final testing technique, accomplished these results. A fluorescent additive in the kerosene, and a black light for the inspector instead of a white one. When additional kerosene is added to the reservoir, a proportional amount of additive is also added to maintain fluorescent brilliance.

Fluorescent Additives Used with Water on Anhydrous Ammonia Tanks

This same company has extended their use of fluorescent material for leak detection even further. Anhydrous ammonia tanks, another high-production, competitive item, are hydrostatically tested. For this testing also, they have added a fluorescent additive to the water for more positive inspection. Results have been equally effective.

Manufacturers of many other types of tanks report the same success with fluorescent materials. Cases protecting the vital transformers in power distribution networks are extremely critical. Leaks resulting either in loss of oil or contamination of the oil can cause transformer breakdown and a power blackout over a wide area. Manufacturers of these cases have long used fluorescent penetrants for in-process leak detection.

Similar inspection techniques are used on tanks for the transportation of oil and gas, for X-ray film processing equipment, and for all types of industrial vehicles. Even large filter units used in oil refineries, and railroad diesel cylinder liners are leak tested with these materials.

In many cases, in-process leak detection with fluorescent penetrant has eliminated the need for a final hydrostatic, submerged air pressure, or soap-bubble test. The biggest advantage that the proper use of these materials offers the manufacturer, however, is their ability to detect leaks in the early stages of manufacturing.

Black Light Detects Leaky Shock Absorbers

One rather unique testing method, relying on the natural fluorescence of hydraulic oil, is of interest. Automotive shock-absorber tubes, after welding top and bottom, are filled with hydraulic oil. Assembly of the shock is then completed and the unit cleaned and painted ready for shipment. Prior to using the black-light inspection technique, the shocks were stored in open cardboard shipping containers for 24 hr. They were then re-packed for shipping in other containers. Any that showed evidence of leakage were removed, dis-assembled, repaired and re-painted.

The manufacturer's present method is to inspect under black light the top and bottom weld of the shock tube. The inspection stand is set up on the conveyor line following the wash station and just prior to the paint booth. Shocks are carried singly on the conveyor on rotating hooks and are automatically rotated in front of the inspectors. Any leakers are indicated by the bluish-white fluorescence of the hydraulic oil. Even though production in one plant has run as high as several thousand shock absorbers per hour, two inspectors with a suitable array of black lights have been able to keep up with production.

Here again, the savings are quite obvious. The cost of re-packaging all production, and the repair of cylinders after painting are eliminated.

Precautions in Use of Fluorescent Penetrant Materials

One word of caution. For a minute leak passage to be indicated by a fluorescent penetrant it must be just that: a free passage, not clogged up. A small amount of moisture or contamination from a previous hydrostatic or air test can cause enough rust or corrosion to completely block a small leak passage. Fluorescent penetrants should be used prior to any other type of test whenever possible.

Conclusion

To summarize briefly, even though a final pressure test may be specified, the in-process steps taken by the manufacturer to assure final quality are not. Any such steps are strictly up to him. Fluorescent penetrant leak detection has clearly demonstrated its ability to qualify as a process-control tool through in-process leak detection.

HEAT-EXCHANGER FABRICATION

Welding and brazing procedures used in the fabrication of nickel-base alloy heat exchangers for elevated-temperature service are described

BY P. PATRIARCA, G. M. SLAUGHTER AND W. D. MANLY

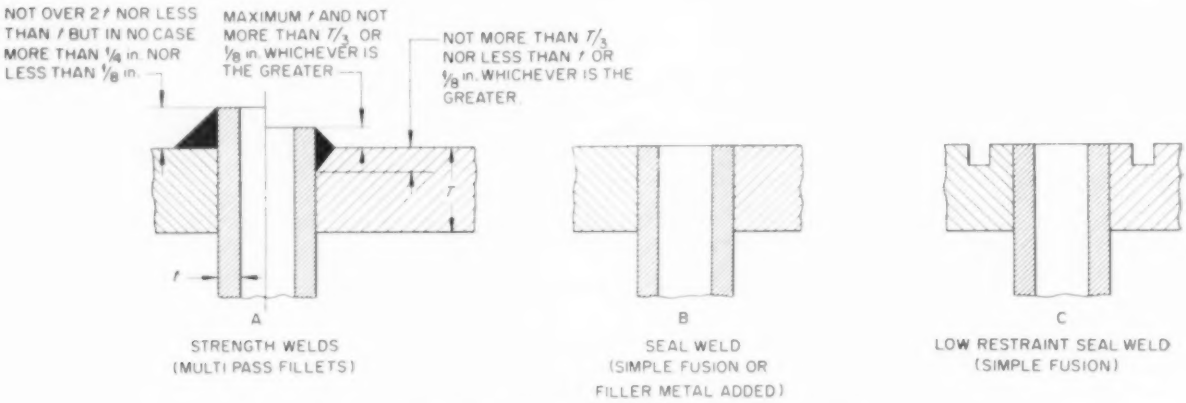

NOT OVER 2 t NOR LESS THAN t BUT IN NO CASE MORE THAN 1/4 in. NOR LESS THAN 1/8 in.
MAXIMUM t AND NOT MORE THAN T/3 OR 1/8 in. WHICHEVER IS THE GREATER
NOT MORE THAN T/3 NOR LESS THAN t OR 1/8 in. WHICHEVER IS THE GREATER
T
t
A
STRENGTH WELDS (MULTI PASS FILLETS)
B
SEAL WELD (SIMPLE FUSION OR FILLER METAL ADDED)
C
LOW RESTRAINT SEAL WELD (SIMPLE FUSION)

Fig. 1 Basic joint designs for tube-to-tube sheet welding

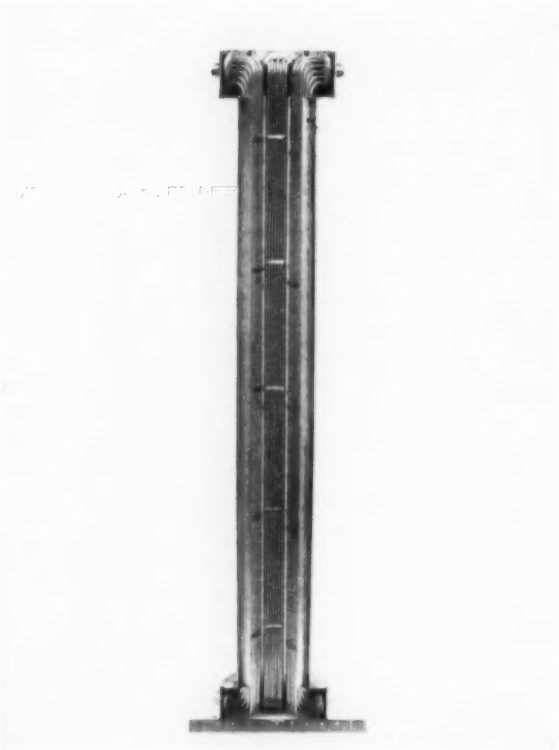


Fig. 2 Half section of an Inconel heat exchanger for liquid-metal test

ABSTRACT. Tube-to-tube sheet welding and brazing procedures, which have been incorporated into the fabrication of nickel-base alloy heat exchangers for elevated-temperature service, are described. Vessel portions of these units are assembled entirely by inert-arc welding procedures using trained and qualified welding operators, who must demonstrate ability to consistently produce weldments of the highest quality.

Prototype components consisting of compact, relatively complex assemblies of thin-walled small diameter tubing have been extensively tested in simulated service and have performed satisfactorily. It is believed that the principle of welding and back brazing insures maximum reliability, and should be incorporated into heat-exchanger fabrication where leak tightness is mandatory throughout its intended service life.

Introduction

The successful fabrication of heat exchangers designed to meet the specific requirements of the power, chemical and petroleum industries can be attributed to knowledge acquired from years of research, from general experience, and from such established practices as those specified by the ASME Boiler and Unfired Pressure Vessel Code. One of the most important joints in any heat exchanger is that used to effect a leak tight seal between the tube and tube sheet. Because of the special service conditions existing in most atomic energy installations, the welded tube-to-tube sheet joint is mandatory.

Joint Design

The design of a conventional joint generally falls into

P. Patriarca, G. M. Slaughter and W. D. Manly are associated with the Metallurgy Division of the Oak Ridge National Laboratory, Oak Ridge, Tenn.

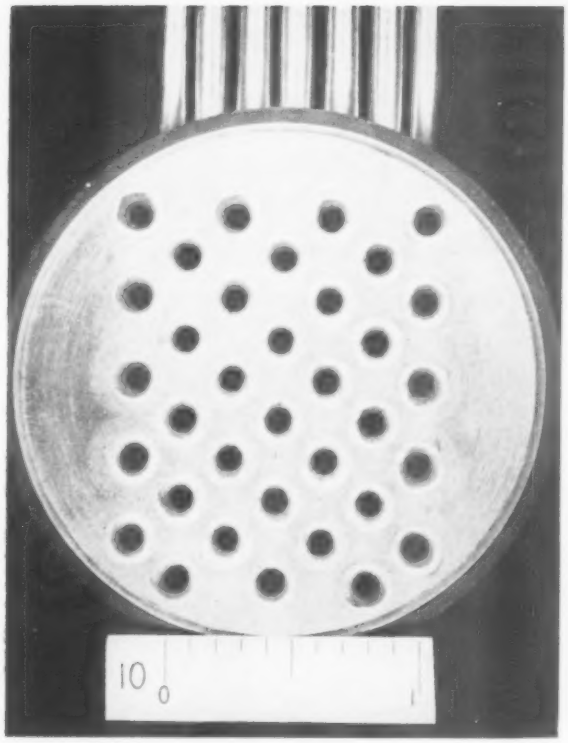


Fig. 3 Manually inert-arc welded tube-to-tube sheet joints for heat exchanger shown in Fig. 2

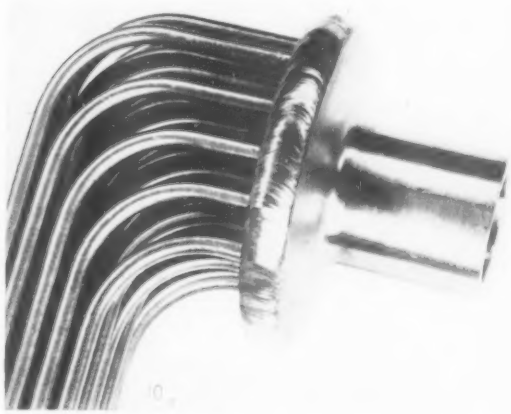


Fig. 4 Nozzle manually inert-arc welded to tube sheet shown in Fig. 3

one of three basic types illustrated in Fig. 1. The ASME Boiler and Unfired Pressure Vessel Code suggests the joints shown in Fig. 1*A* for applications where tubes are of sufficient diameter and wall thickness to permit the addition of filler metal by the metallic-arc or inert-arc processes. Where seal welds are acceptable, the elementary joint design shown in Fig. 1*B*, incorporating simple fusion of the tube into the tube sheet, is satisfactory. This procedure, however, is not recommended where the structural materials are crack sensitive when welded under conditions of restraint. The degree of restraint in a joint can be diminished significantly to reduce both cracking tendencies and

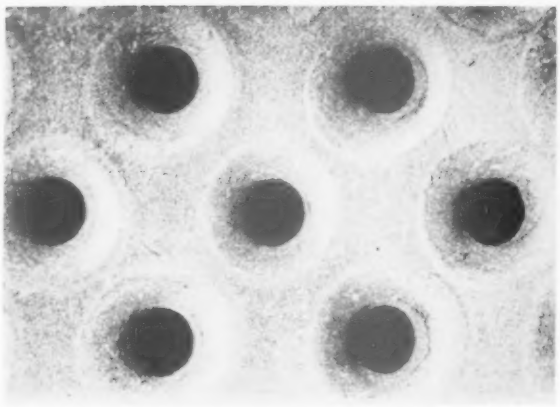


Fig. 5 Peripheral cracking of the tube-to-tube sheet welds during cyclic test

tube-sheet distortion by the use of the trepanned joint shown in Fig. 1*C*. Aside from increased cost, the use of this design is limited by ligament size and the degree of machining difficulties imposed by various tube-sheet contours.

Many of the heat-exchanger designs under consideration for atomic energy applications are unusual and unconventional in their dimensions, complexity, and material selection. Representative of the unusual heat transfer and process media peculiar to this industry, are the liquid metals, the use of which at elevated temperatures may introduce extremely severe corrosion problems. The tube-to-tube sheet joint, called upon to withstand both the environment and the generally unavoidable thermal stresses, must be of the highest order of integrity. The existing applicable technology has often been inadequate, thereby necessitating the development of unique fabrication methods to satisfy the stringent requirements.

The Inconel heat exchanger illustrated in Fig. 2 in half section was fabricated by manual inert-arc welding, and utilized thin-wall tubing, the joint design being that shown in Fig. 1*B*.

A total of 420 tube-to-tube sheet joints were equally distributed among twelve nozzles, one of which is shown in a partial state of completion in Fig. 3. A tube bundle nozzle as completed is shown in Fig. 4.

Joint Quality

The testing program, incorporating both steady-state and cyclic-temperature conditions, was terminated prematurely as a result of the failure of several tube-to-tube sheet joints. The individual tube bundles were removed and dissected for inspection and metallographic examination after test. Several tube sheets were characterized by multiple failures in the form of peripheral cracks, a typical example of which may be seen in Fig. 5. A metallographic section of a typical fracture is shown in Fig. 6. Examination of a number of tubes which had not leaked revealed fissuring in various stages of propagation.

Since the examination of numerous as-welded test

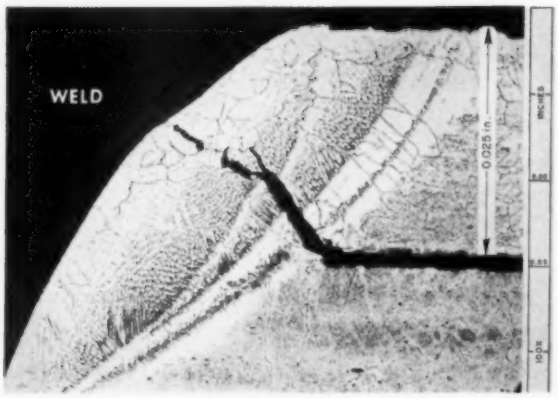


Fig. 6 Photomicrograph of cracked tube-to-tube sheet weld after test. X 100. Etch: 10% oxalic acid-electrolytic. (Reduced by 50% upon reproduction)

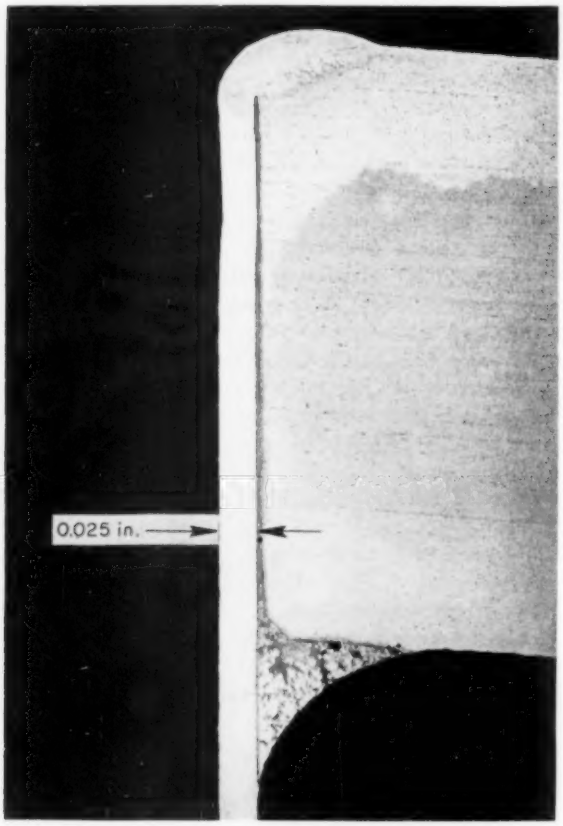


Fig. 7 Inconel tube-to-tube sheet joint back brazed wth Ni-B-Si alloy. X 12. Etch: 10% oxalic acid-electrolytic. (Reduced by 20% upon reproduction)

samples during the development of a suitable welding procedure failed to reveal the presence of these microfissures, it was concluded that the initiation and propagation of the majority of the cracks occurred during thermal cycling. Such behavior could reasonably be expected under the conditions of service by virtue of the nature of a tube-to-tube sheet joint itself. The

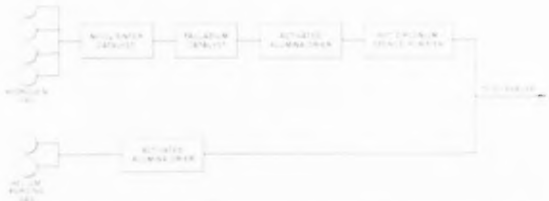


Fig. 8 System block diagram of brazing-gas purification

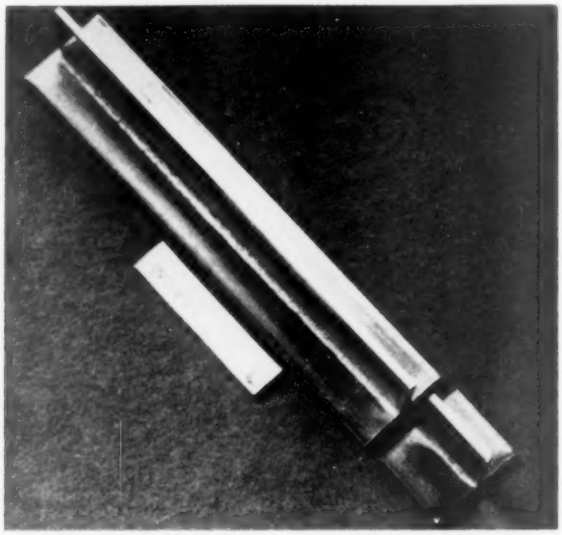


Fig. 9 Inconel T-joint brazed at 1050° C in dry hydrogen

unfused portion of the joint is unavoidable and constitutes a notch.

An obvious solution to the problem would be to relieve the notched condition by the use of a suitable back braze such as is shown in Fig. 7. In this photomicrograph, an 0.025-in. wall Inconel tube has been brazed into the tube sheet with a nickel-silicon-boron brazing alloy corresponding to AMS 4778. It may be seen that this technique serves to eliminate the notch by filling the annulus between the tube and tube sheet and by providing a smooth fillet for optimum stress distribution. Further, back brazing would tend to supplement the weld in the event of the occurrence of undetected flaws during welding.

Selection of Brazing Alloy

The selection of an acceptable brazing alloy for a specific application is dictated by its resistance to the corrosion environment and the mechanical properties of the alloy at the operating temperatures of interest. The complexity of most heat exchangers require that furnace-brazing procedures be employed with the brazing-alloy composition generally requiring a purified inert- or reducing-atmosphere such as hydrogen dried to a dew point of −70 to −100° F. A schematic diagram of a suitable drying train is shown in Fig. 8. This system has been used successfully for brazing of prototype heat exchangers where the flow rates re-

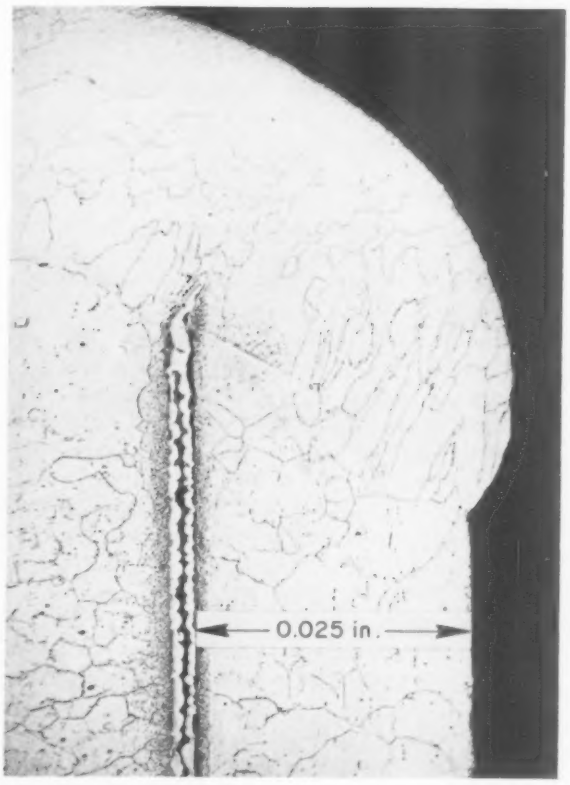


Fig. 10 Root crack in Inconel tube-to-tube sheet joint remedied by back brazing. X 75. Etch: oxalic acid-electrolytic

Fig. 11 Gross porosity in Inconel tube-to-tube sheet weld. X 24. Etch: oxalic acid-electrolytic

quired for satisfactory brazing were approximately 100 cu ft of gas per hour.

Briefly, the determination of the corrosion resistance of the brazing alloy is accomplished by encapsulating brazed joints in the environment of interest and holding for pre-determined periods in the desired temperature range. The specimen generally consists of a segment of an inverted dry-hydrogen brazed T-joint such as shown in Fig. 9. Following this screening test, the alloy is incorporated into a test heat exchanger to determine its resistance to corrosion under dynamic testing conditions.

Procedures and Equipment

Although back brazing can serve to compensate for inadequate welding procedures to a certain extent, the stringent service requirements make the production of flawless welds highly desirable. Such flaws as an occasional root crack can be remedied by back brazing as shown in Fig. 10, but major flaws such as that shown in Fig. 11 are to be avoided. This porosity was attributed to a relaxation of pre-cleaning procedures and less than optimum fitup. It may be noted that approximately 0.002 in. of sound metal remains as a corrosion barrier. Without back brazing the existence of such a flaw would result in premature failure since detection would be nearly impossible. Dye-penetrant inspection would be inadequate because of the sub-surface nature of the flaw. The most sensitive radiography would be required to detect a pore approximately 0.030-in. in its greatest dimension. Accurate interpretation of the radiographs would be obscured by the close-packed tube array and the general complexity of the heat-exchanger tube bundle.

Although highly skilled craftsmen can be trained to fabricate tube-to-tube sheet joints which are consistent in the required quality, removal or minimizing the human element in such critical applications is considered advisable if the occasional gross flaw is to be avoided. Semiautomatic apparatus, as shown in Fig. 12, can be assembled at minimum cost from commercially avail-

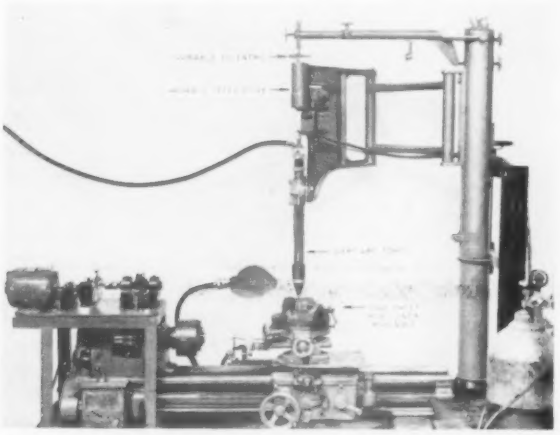


Fig. 12 Laboratory tube-to-tube sheet welding head and welding lathe

able components. The diameter of rotation required for a given tube diameter can be acquired by adjusting the eccentric at the top of the variable-speed drive assembly as shown. A close-up photograph of the eccentric is shown in Fig. 13. The work is positioned under the inert-arc welding torch, and the proper rotational pattern is determined visually by a skilled operator or by a suitable indexing head if desired.

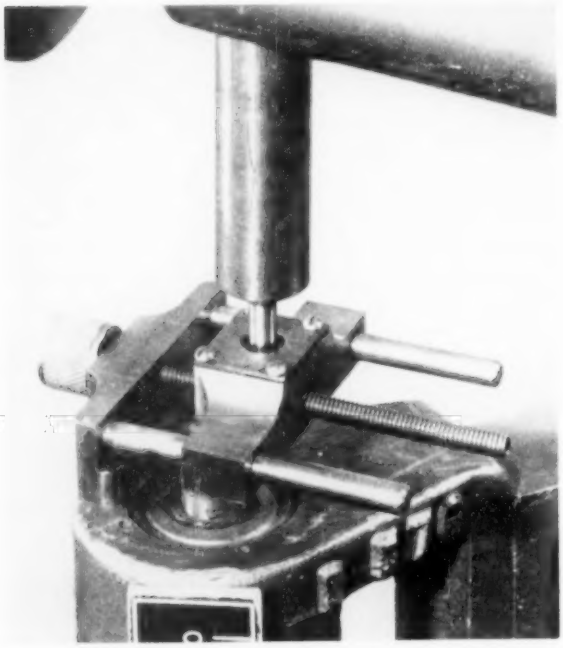


Fig. 13 Close-up of variable eccentric

A satisfactory power supply for such an installation is described schematically in Fig. 14. The essential components are a direct-current source such as a motor generator with a remote open-circuit voltage attachment for current-decay purposes, a welding contactor and a high-frequency oscillator to provide remote striking. An auxiliary timer circuit, responding to changes in arc voltage, has also proven useful in some applications.

The tube-to-tube sheet joints of a number of test heat exchangers, such as that illustrated in Fig. 15, have been successfully produced with the laboratory apparatus described using a welding procedure comparable to that presented in Fig. 16. A typical tube-to-tube sheet joint after back brazing is shown in Fig. 17. The tube sheet end of the heat exchanger is shown positioned for welding in Fig. 18. It may be noted that the welds appear bright and clean in the as-welded condition, a result of the application of meticulous assembly procedures, pre-cleaned parts, and adequate inert-gas protection during welding.

Figure 19 shows the underside of the tube sheet with the Ni-Si-B brazing alloy pre-placed in the form of cast rings. These were attached by electric-resistance spot welding in advance of the assembly and subsequent welding of the tubes into the tube sheet. The tube sheet is shown in Fig. 20 after welding into a

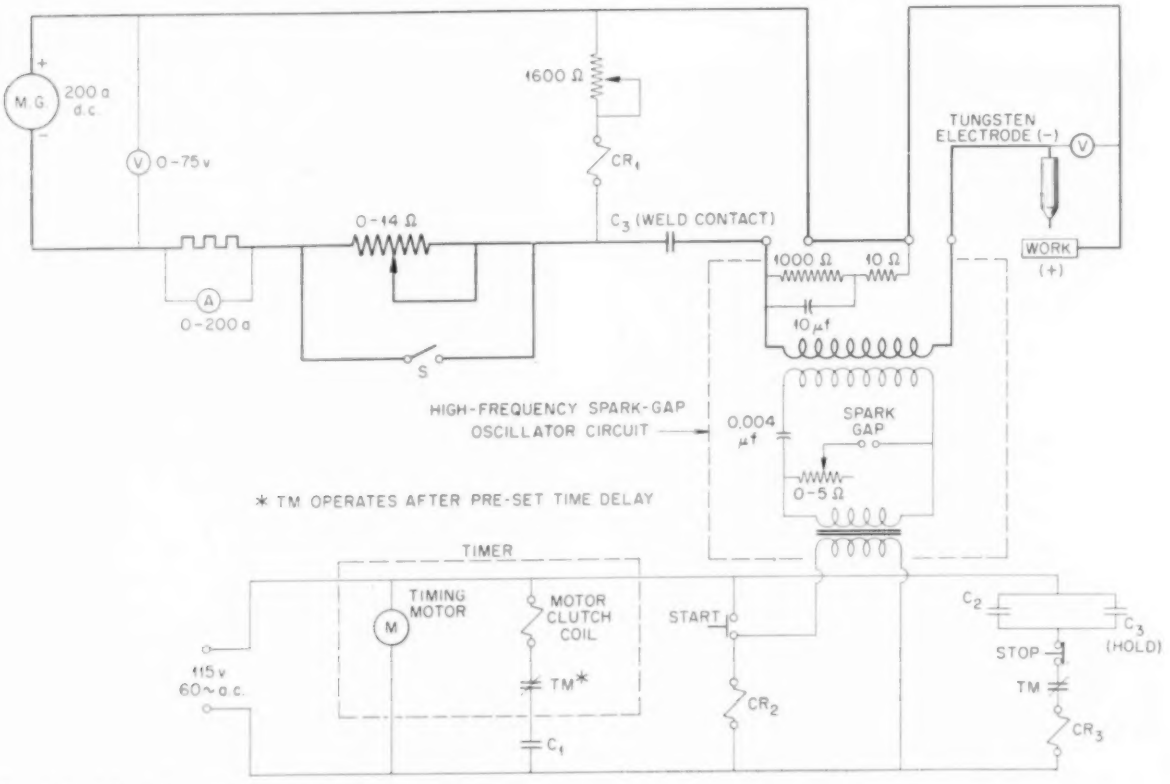


Fig. 14 Schematic diagram of inert-arc welding circuit

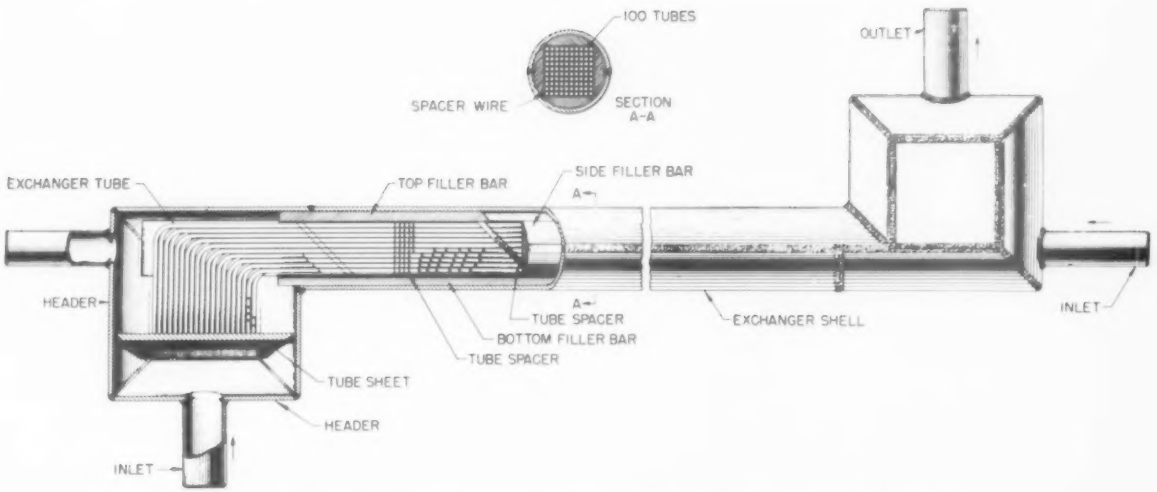
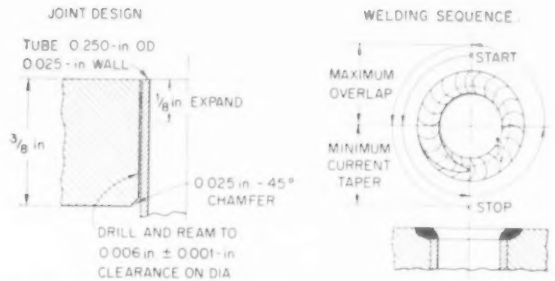


Fig. 15 Typical test heat exchanger for liquid-metal, elevated-temperature service



WELDING CONDITIONS

CUP SIZE - 3/8-in. OPENING (MINIMUM)
ELECTRODE - THORIATED TUNGSTEN 3/32 in. AND POINTED
ELECTRODE PROJECTION FROM CUP - 1/4 in.
ELECTRODE SWING - 0.270-in DIA
ARC DISTANCE - 0.050 in.
ARGON FLOW THROUGH TORCH - 30 ft³/hr
ARGON BACKUP GAS FLOW - 20 ft³/hr
ARC CURRENT - 70 ± 5 amps D.C.S.P.
ELECTRODE TRAVEL SPEED (PERIPHERAL) - 6 in./min

Fig. 16 Procedure for Inconel tube-to-tube sheet weld

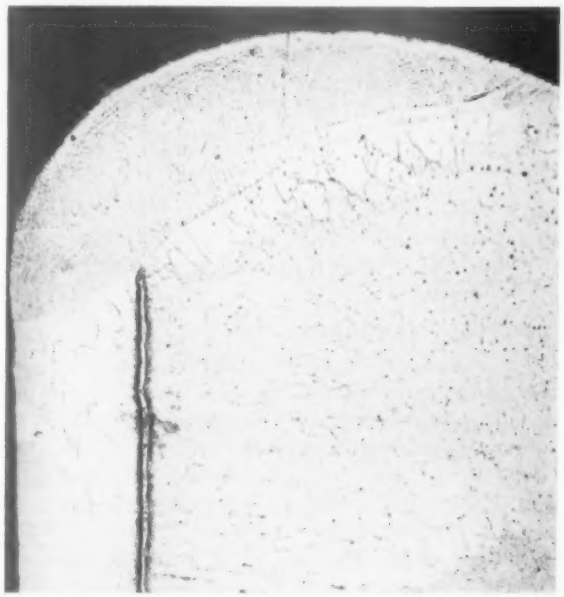


Fig. 17 Inconel tube-to-tube sheet joint machine welded and back brazed with Ni-B-Si alloy. X 30. Etch: oxalic acid-electrolytic

partially completed housing in advance of the brazing operation. All other welding was performed by highly-skilled and extensively-trained and tested inert-arc welding operators using welding procedures qualified in accordance with the ASME Code. In view of the intended service, the quality standards are maintained at an exceptionally high level. All flaws detected by visual, dye penetrant and radiographic methods are removed and repaired with the exception of occasional porosity (no more than one pore in any one inch in excess of 0.030 in. in diameter) in the heavy sections.

Furnace brazing is carried out in a welded retort in an atmosphere of dry hydrogen. The heating and cooling rates are controlled at 300° C per hour to minimize distortion. A holding time of 30 min at 1050° C has been found adequate to insure good flow and filleting of the AMS 4778 alloy. The heat exchanger is inspected after brazing as shown in Fig. 21. Following testing with a helium mass-spectrometer leak detector, the remainder of the housing is completed, critically inspected, and if accepted, is submitted for test operation.

Following a pre-determined test schedule, the units are disassembled and the welded joints examined. Examination of numerous heat exchangers to date has failed to reveal a single tube-to-tube sheet joint failure,

Fig. 18 Tube sheet positioned for welding

ample indication of the ability of properly welded and subsequently back-brazed tube-to-tube sheet joints to withstand extremely severe service at elevated temperature.

Industrial Acceptance

The success of the laboratory apparatus described in the fabrication of reliable heat exchangers has led to its adoption by a number of industrial concerns. The equipment has been improved by precise mechanisms, adapted for production by suitable indexing and positioning attachments, and can be rendered universal to the extent that reasonable curvatures on tube sheets can be accommodated by automatic arc-length control.

The inert-arc welding procedures developed and in use at Oak Ridge National Laboratory have also received wide industrial acceptance. Industrial training programs and qualification testing are being conducted in cooperation with the Laboratory thereby providing the highly-skilled welding operators so necessary for the production of the reactor-grade weldments and the continued advance of reactor technology.

Acknowledgment

The authors wish to acknowledge the contribution of T. R. Housley, Engineering and Mechanical Divis'on, who developed the inert-arc welding procedures, and B. MacDowell and C. E. Shubert, Welding and Brazing Laboratory of the Metallurgy Division, who assisted in the development of the tube-to-tube sheet welding and brazing procedures and apparatus.

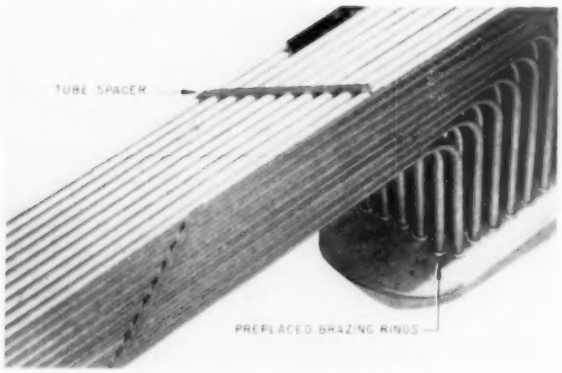


Fig 19 Underside of tube sheet showing preplaced Ni-Si-B alloy

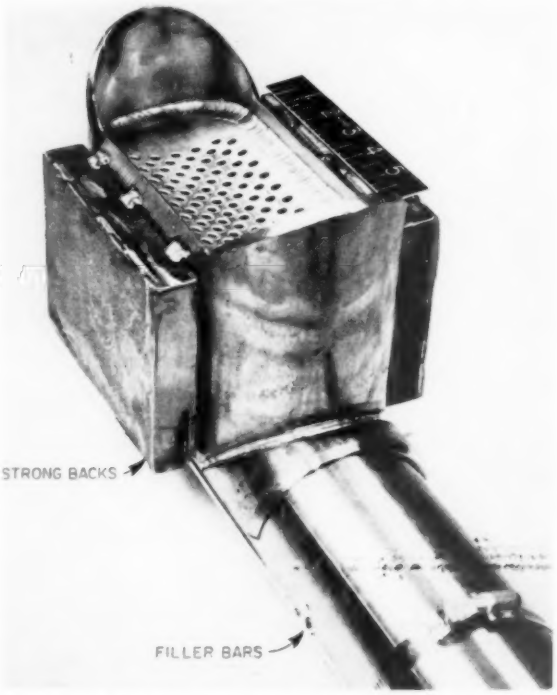


Fig. 20 Tube sheet as welded into its header

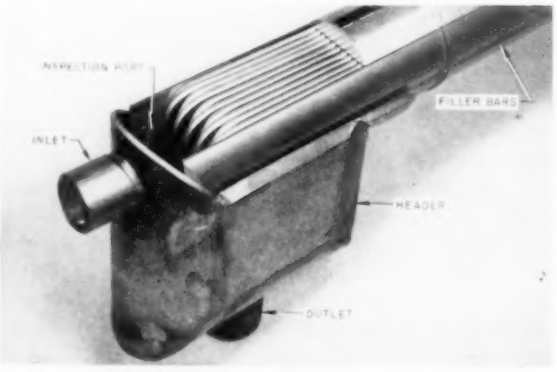


Fig. 21 One end of heat exchanger after brazing as positioned for inspection of brazed joints

THE PROXIMITY LIMIT SWITCH— A VERSATILE TOOL FOR INDUSTRY

Improvements in reliability, operating life, accessibility and adaptability to existing and new systems concepts, without impairing ease of understanding and application, are the objectives of program undertaken to develop a magnetic proximity sensing device

BY R. C. MIERENDORF

Introduction

The ever-increasing complexity of electrical control systems has led in recent years to specialization in engineering approach. As the individual fields of specialization expand, it is becoming more and more common to divide development effort among three specific areas defined by the differences in function which are involved.

These three functions of a control system are generally identified as (1) the power or actuating means, (2) the coordinating, computing or logic functions and (3) the sensing or input means. The first two are generally well-understood by the control systems engineer; the first because common devices such as magnetic contactors and relays have been in use in substantially their present form for many years, and the second because of the great impact which recent progress in logic or computing technology has had on control system thinking. This latter field, particularly, has received a great amount of attention in the last two years and a substantial portion of present engineering effort is being devoted to development of improved logic components.

The third area, that of sensing or input, deserves and is currently beginning to receive, more nearly its share of engineering thought. In the past it has been neglected, relatively speaking, and yet it offers tremendous opportunity for significant, even revolutionary progress. This field of input technology is the subject of the following comments which will deal with recent progress along one avenue of approach.

The Limit Switch Problem

Efforts to improve the performance of existing components began with a careful study of the factors of size, complexity, cost, operating life, ease of installation and maintenance. It soon became evident that serious basic problems resulted from the common practice of thinking of sensing components primarily in terms of mechanical devices converting only simple motion into electrical signals. New requirements to translate complex motions into precise signals with practically infallible reliability made selection of input devices increasingly difficult. The importance of designing adequate "seeing" devices became obvious and may be compared to the relative importance of sight to the operator of an airplane. The problems of supplementing or amplifying the pilot's function of controlling the various parts of his aircraft are simple in comparison to those which have been solved by the extremely complex radar components designed to augment his ability to "see."

Until recently, most sensing problems in control systems were attacked as application problems for conventional mechanical limit switches. All of us are familiar with the "desperation engineering" typical of so many applications. These jury-rigged linkages frequently overstressed the mechanical parts of the switch and in many cases were poor compromises at best for the ultimate goal desired. Many an otherwise adequate system is thus severely limited in accuracy and reliability by the inadequacy of the "sensing" function.

To overcome this drawback a program of development (along a well-known but little-travelled avenue) was undertaken to design a magnetic "proximity" sensing device. Objectives of the program were to improve substantially the reliability, operating life, accessibility, and adaptability to existing and new systems concepts, without impairing ease of understanding and application.

Application Notes

The new concept immediately opened broad fields of

R. C. Mierendorf is associated with the Square D Co., Milwaukee, Wis.

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application, many of them unsuitable to previous "limit switch" practice. Some of the broader objectives to which the new concept offers improved solutions may be listed as follows:

Limit Switch

1. On conveyor systems, particularly where irregular parts necessitate the use of special operating arms on conventional switches.

2. On conveyor lines where parts are too small or lightweight to provide the required operating force for conventional limit switches.

3. On conveyor systems where product surface finish is susceptible to damage or marring by physical contact with conventional switches.

4. On control systems where highly repetitive operations require operating life in excess of that available with conventional limit switches.

Positioning Device

1. On machine tools to indicate angular position, index position or displacement, where selsyn systems are usually required.

2. On machine tools to initiate functions such as tool cuts at predetermined locations.

3. On special machine applications, such as contour lathes, where information requires transfer from a master pattern to a working piece.

Speed Control

1. As an input for an adjustable speed drive for d-c motors where speed is a function of position or displacement.

2. As a monitor to trigger a control function when rotating machinery diverges from a preset speed of rotation.

Counter

1. To measure rotational speed.

2. To count objects on a conveyor system.

Inspection Tool

1. To detect presence of ferrous material in product or refuse.

2. To measure distances or levels.

3. To detect vibration and measure within preset limits.

4. To control measuring equipment within preset limits.

Protector Panel

1. To monitor machine loading and unloading to prevent machine operation without presence of material or doubling up of materials such as may occur with stamping presses.

Unusual Ambient or Atmospheric Conditions

1. To operate as a limit switch in explosive atmosphere.

2. To operate as edge register control for hot steel strip in rolling applications.

3. To control conveyor feeding steel rods into and out of heat-treating furnace.

4. To control movement of automatic paint spray equipment in spray booths.

5. To control washing and rinsing operations on conveyor lines.

6. To operate as limit switch or metal detector under water.

Design Objectives

With these immediate applications in mind, more specific design objectives could be established.

1. The sensing element or transducer should be easily connected for use in conventional relay circuitry or in static control circuitry.

2. The transducer should be capable of actuating a large load when used with an auxiliary power amplifier such as a relay, thyratron switch or magnetic amplifier.

3. The transducer should contain no moving or operating parts.

4. Life and reliability should be beyond all normal requirements.

5. Cost should be as low as possible, consistent with good design.

6. The transducer should be suitable for operation in a wide range of environmental conditions.

7. Operation at power line frequencies should be practicable.

8. Speed of response should be suitable for machine tool and conveyor applications.

9. Remote mounting with the possibility of literally burying the transducer in a machine should be feasible. This would allow the sensing action to take place at the most desirable location rather than at a compromised location.

10. Shock and vibration encountered in normal machine tool installations should not limit application.

11. Various sizes of transducers should be available depending upon complexity of parts or pieces to be monitored.

The transducer described hereafter approaches these design objectives. It has been called the proximity limit switch, magnetic eye, or simply mag-eye.

Proximity Limit Switch Description

Basically, the proximity limit switch consists of a transducer unit and a control unit. The control unit includes a voltage amplifier, a phase-shift detector and provides an output signal capable of operating a relay or static switch. The relay contacts are usable for the control circuitry in a manner similar to conventional limit-switch contacts.

The heart of the control circuit is the transducer unit. Mounted remotely, it is connected to the control panel by a cable. Operating on the bucking field principle used in differential transformers, the transducer consists of three solenoid-type coils mounted on a common core. Referring to Fig. 1, the outside coils 1 and 3 are similar in size and number of turns and are connected with their fields opposing. They are energized from an a-c supply. The center coil 2 is known as a signal or output coil. The voltage induced in the center coil is proportional to the resultant flux in the outer or driving coils. In order to achieve a voltage gain in the trans-

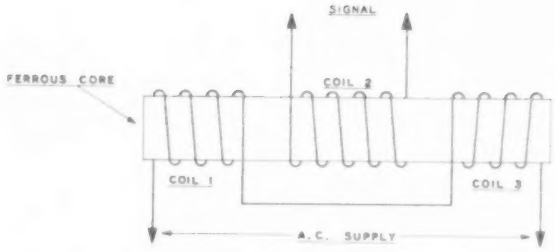

Fig. 1 Simplified transducer

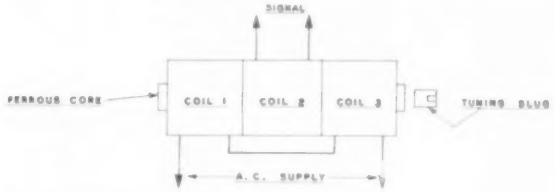

Fig. 2 Transducer with tuning slug

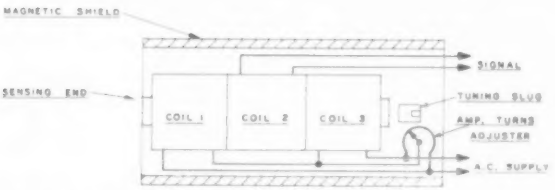

Fig. 3 Complete transducer

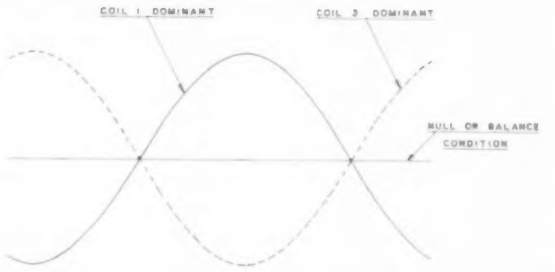

Fig. 4 Signal voltage of coil 2—transducer tuned to null

ducer, the signal coil has many more turns than the driving coils.

The coils are wound on a bobbin with a hollow center. A magnetic rod of approximately the same length as the bobbin assembly is placed in its hollow core. This magnetic core acts to concentrate and focus the fields set up by the outer coils. If the core is correctly positioned, the field of coils 1 and 3 cancel, resulting in a zero signal output of coil 2. This is commonly referred to as a null-condition. In order to adjust for a null or zero signal output, the core must be free to move along the axis of the coils, or a tuning slug may be fitted on one end of the core as shown in Fig. 2. Moving the core to either side of the null position will increase the flux originating in the driving coil at that end, resulting in a signal output from coil 2. Because the fields of the driving coils are 180° out of phase, movement of the core in the opposite direction will produce a similar signal but of opposite polarity. If the core is adjusted for null, introduction of magnetic material in the field of either driving coil will similarly reduce the reluctance of its magnetic path, increase its flux and produce an output signal of the corresponding polarity. Because of the focusing action of the magnetic core, the most sensitive position for the field disturbance is along the axis of the coil assembly.

One end of the coil assembly is designated as the pickup or sensing surface. In order to actuate this transducer unit, magnetic material must be passed near its pickup end. The remainder of the coil assembly is completely surrounded with a magnetic jacket. The jacket shields the coils from external interference on all surfaces except the pickup end. In the following discussion, coil 1 is the driving coil on the sensing end of the core assembly and coil 3 is the driving coil at the opposite end as shown in Fig. 3.

Calibration and Operation

The undisturbed transducer output signal is initially calibrated with the aid of two magnetic circuit adjustments. The position of the magnetic core with respect to the driving coils is adjustable, in this case by a threaded tuning slug fitted in one end of the core. The second adjustment is made on the relative current flowing in each driving coil by shunting the coils with a balancing potentiometer.

By careful use of both adjustments (tuning slug and coil ampere turns), the driving coil magnetic field patterns can be made to cancel perfectly, resulting in zero output for coil 2 shown in Fig. 4. A shunt capacitor is placed across the output-coil terminals to provide filtering of harmonic frequencies, which become objectionable at and near the balance or null condition. With the coil fields perfectly balanced, disturbance of coil 1 with external magnetic material produces an output signal of corresponding polarity. Disturbance of coil 3 produces a similar signal, but 180° out of phase. Therefore, two choices of output-signal phase are available, these being 180° apart. There are no intermediate degrees of phase relationship. In order to produce a signal change sufficient to actuate an amplitude-controlled device, considerable magnetic disturbance is necessary. If intermediate values of phase shift were obtainable, the sensitivity of the unit would be increased. Most phase-sensitive devices may be controlled with much less than a 180° phase shift. For example, a 30° phase shift of the grid signal on a thyratron tube will assure ionization of the tube. It becomes obvious that the magnetic sensitivity of the transducer can be increased if only a small percent of the total possible phase shift is required for operation.

A continuous change in signal phase can be obtained if the output passes through a minimum point which does not reach perfect balance. This oscillogram is

shown in Fig. 5. Readjustments of the tuning slug and balancing potentiometer may be utilized to produce a sinusoidal minimum-signal output when the transducer output is undisturbed. The polarity of this minimum signal is approximately midway between the output voltage polarities associated with each of the driving coils.

Figure 6 is a vector diagram representation of the output voltage. Introduction of the magnetic material in coil 3 field will shift the signal ahead in phase while a similar disturbance in the vicinity of coil 1 will produce a backward phase shift. Because a backward or lagging phase shift will move the positive polarity of the signal into the leading edge of the anode-cathode voltage of a thyratron phase shift detector, coil 1 is selected as the pickup surface. The phase shift is now continuous, being dependent upon the magnitude of the disturbance, the E1 vector increasing from OA to OB, and the angle φ increasing accordingly. As the external disturbance becomes appreciable, an increase in signal amplitude also occurs. However, the first 30° of phase shift is sufficient to actuate a phase-sensitive thyratron, and within this region, no appreciable amplitude increase occurs. Further increases in field disturbance result in a maximum phase shift of approximately 130° and an amplitude increase of 100 times. Once triggered, the phase-sensitive control will remain in that state regardless of increased magnetic disturbance of any degree. Resetting will occur only after the magnetic object has receded from the transducer field.

Phase Detection

A saturable reactor or magnetic amplifier can be designed for this purpose of phase detection. In addition, these devices supply the power gain necessary for coupling into most external power and control circuits. Other electronic or magnetic devices which respond to a phase change could also be applied.

Since a thyratron was selected as the phase detector-power amplifier in the control unit, its operation will be described more completely. The thyratron is held nonconductive because the a-c signal voltage between grid and cathode is of opposite polarity to the a-c anode-cathode supply. As the signal changes phase due to field disturbance, the grid-cathode voltage shifts backwards (that is, lags) becoming more in phase with the plate supply, allowing the tube to ionize. The load in the anode circuit is thus suddenly energized. The load may be a pilot relay with heavy-duty pushbutton contact ratings or a transformer yielding a voltage pulse capable of operating static control components.

Several changes must take place on the signal from the transducer before it can work into the phase shift detector circuit. Minor phase adjustments are made on the undisturbed standby signal after it leaves the transducer. This is necessary in order to bring it into proper in-phase relationship with the line voltage supply. A resistance-capacitance input network performs this function before the signal enters the voltage amplifier

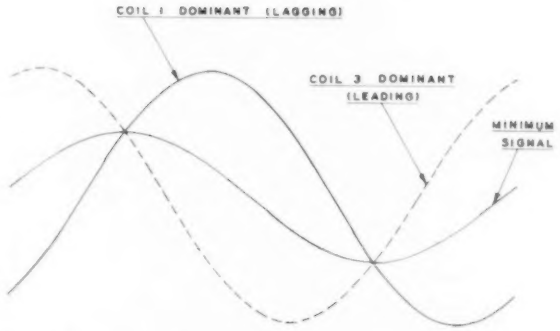

Fig. 5 Signal voltage of coil 2—transducer tuned to minimum

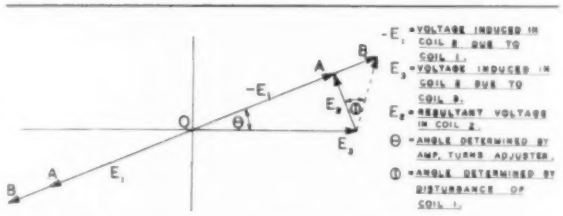

Fig. 6 Vector diagram showing signal voltage *E2* and phase angle φ

The major signal change required is amplification. The small signal output from the transducer must be amplified in order to control effectively the phase detector-power output circuit. Voltage amplifiers utilizing vacuum tubes, transistors and magnetic components are all capable of providing the necessary signal gain. The functions of a voltage amplifier and a phase-shift detector could be performed by a single device. A conventional magnetic amplifier has the necessary properties to be utilized as both an amplifier and a phase-shift detector. Regardless of how they are performed, both functions, amplification and phase-shift detection, are vital to the circuit operation. In a typical circuit a vacuum tube is used for signal amplification. The amplifier output is then resistance coupled into the thyratron grid circuit.

Auxiliary Features

Other features may be considered desirable in operation of this unit. These will be discussed briefly.

A sensitivity adjusting means is usually required, especially in those applications requiring response to certain selected disturbances. In the circuit described in the previous paragraph, this can be accomplished in several ways. One method is to use an adjustable negative d-c voltage in series with the signal from the amplifier before it is sent to the phase-shift detector. A second method is to advance or retard the phase of the signal in the control circuit following the transducer. In either case, as more d-c bias is selected or as the signal phase is advanced, more signal-phase shift must be accomplished, and consequently, a larger external disturbance must exist. The inverse is also true, for with less d-c bias and a retarded signal phase, less dis-

turbance is required for operation. A less expensive, but thoroughly acceptable method is to position the transducer mechanically for desired sensitivity. This procedure is aided by provision in the mounting means, and follows conventional limit-switch installation practice.

In some applications it has been found necessary to provide a minimum output time adjustment. This condition develops when the disturbing object is in the transducer field for a very short period of time. Thus the power-output circuit may not be actuated long enough for proper operation of external devices such as valves and relays. It is possible to provide a fixed or adjustable time lag before reset with internal circuitry. However, in the interest of simplicity, it is recommended that the basic control unit be combined with an additional separate adjustable time-delay unit when this requirement arises. The time-delay unit may be fully electronic or magnetic, the choice being made by the circuit designer.

A number of applications have required circuitry that is normally in the "on" position, and is turned "off" by a disturbance in the field of the transducer. Thus a failure of any portion of the transducer or control unit would also appear as a signal and cause the unit to be in the "off" position. The entire control system must be considered and evaluated in order to select the type of operation which will provide "fail safe" features. With the transducer described previously, it can readily be seen that adjustment of the tuning slug and balancing potentiometer determines which driving coil is dominant. Referring again to Fig. 6, it is obvious that the tuning adjustments could be made to cause the signal voltage to shift ahead in phase with a disturbance of the transducer field, thus removing the turn-on signal to the thyratron and causing the output signal to disappear.

Conclusion

The principle of operation of this device is applicable over a wide range of supply frequencies. Certain applications will require units designed for definite frequency levels. These levels may be selected to provide optimum performance with specified requirements of sensitivity and speed of operation.

The proximity limit switch as described is a versatile tool for industry with extremely broad possibilities of application. It will not, of course, replace all existing input devices. Rather, the system design approach should determine the most suitable device, whether it be a conventional or proximity switch. There is little doubt, however, that the proximity limit switch will be a useful device contributing much to reliable control systems.

Acknowledgment

The author wishes to express his appreciation to C. F. Meyer of the Square D Co. for his cooperation in the preparation of this paper.

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A SATISFACTORY BASE-QUALITY STEEL FOR BOTH RIVETED AND WELDED STRUCTURES

In author's opinion, specification ASTM A7 should be revised to indicate that it is suitable for use in either riveted or welded structures, allowing the specified 60,000-psi minimum tensile strength to remain, but adding a carbon limitation of 0.30% on ladle analysis up to a maximum permissible thickness for welded structures of 2 in.

BY J. O. JACKSON

ABSTRACT. At the present time, the only available base-quality steel for both riveted and welded structures is "Tentative Specification for Steel for Bridges and Buildings," ASTM A7-56T. Steel furnished under this specification is usually suitable for welding, but the specification will permit steel being furnished which is not the most suitable for welded structures. Since the new specification "Tentative Specification for Structural Steel for Welding ASTM A373-56T" is now available, it is believed that engineers will be more inclined to specify the A373 grade, although it is shown in the following article that over 99% of the steel received under the ASTM A7 specification is suitable for welded structures not susceptible to appreciable impact loading or low-temperature service, and that the additional cost of grade A373 is, therefore, not justified for such structures, and for steel shapes, the steel furnished will in all probability be identical with that furnished under grade ASTM A7. It is believed that severe hardships would be imposed on the fabricating industry if it became necessary to stock a variety of sections in the two specifications and that real economy would result in the adoption of one grade equally suitable for either riveted or welded structures.

Introduction

Steel for bridges and buildings, ASTM A7-56T, *as specified*, is not suitable for welded structures for the following reasons:

1. The maximum carbon content is not limited by the ASTM A7 specification and it is therefore possible to receive material higher in carbon than is generally considered desirable for ordinary welding. It is generally agreed that steel having a ladle analysis of carbon higher than 0.30% should be given special treatment during welding, such as the use of low-hydrogen electrodes or some degree of preheating and that steel with carbon above these limits should not be production welded in fabricating shops and in the field without such precautions.

2. Steel made under the acid bessemer process is permitted in specification ASTM A7 for parts of structures not subject to dynamic loads, except that it shall not be used for bridges. Acid bessemer steel is not limited as to carbon and may be furnished with excessive carbon, which would make it unsuitable for production welding.

3. ASTM A7 steel as specified may result in a steel which has a high transition temperature and may be subject to brittle failure under impact at ordinary ambient temperatures.

Table 1—Percent of All ASTM A7 Shapes Received During 1955 with Carbon Content Lower Than Stated Percentages

Carbon, % (1)	*Wt. of steel, tons*	*Percent having lower carbon (2)*
0.14	1 590	0.00
0.15		0.03
0.16	29 193	0.03
0.17	97 289	0.56
0.18	49 025	2.31
0.19	191 083	3.19
0.20	396 794	6.63
0.21	729 118	13.77
0.22	1076 820	26.90
0.23	890 750	46.28
0.24	1120 428	62.31
0.25	506 563	82.48
0.26	353 171	91.60
0.27	83 728	97.96
0.28	22 088	99.47
0.29	1 135	99.87
0.30		99.89
0.31		99.89
0.32	6 320	99.89
Totals	5555 095	

NOTE: (1) Carbon percent is on ladle analysis.
(2) Percent of steel by weight having a carbon content less than shown in column 1.

J. O. Jackson is President, Engineering Development Co., Coraopolis, Pa.

Two and one-half million gallon elevated steel water tank at Pittsburgh, Pa., illustrating the use of base-quality steels for welded structures

4. There have been many cases of cracking occurring when ASTM A7 steel has been welded in ambient temperatures below 50° F and instances are known where parts of welded members have cracked and even completely separated during moderate impact in cold weather.

The above paragraphs 1 to 4 refer to ASTM A7 steel *as specified* and *as occasionally* received, particularly in the larger thicknesses. The comments in the above paragraphs 1 to 4 do not, however, represent the experience of one fabricating shop with ASTM A7 steel *as received* from the rolling mill supplying this shop.

Table 1 is a summary of all ASTM A7 shapes received by this shop during the year 1955 tabulated by carbon percentage so as to show the percent by weight of the total steel received having less than any given

carbon content. The table shows that 99.87% of the steel had a carbon content of less than 0.30% of ladle analysis.

Table 2 shows similar data for A7 angles, bar and channels and shows that 98.11% of these shapes had less than 0.30% carbon.

Table 3 gives similar data for A7 plates of all thicknesses and indicates that 98.7% of all plates received have carbon content less than 0.30%.

Table 2—Percent of All ASTM A7 Angles, Bars and Channels Received During 1955 with Carbon Content Lower Than Stated Percentages

Carbon, % (1)	*Wt. of steel, tons*	*Percent having lower carbon (2)*
0.18	23 560	0.00
0.19	103 660	1.03
0.20	119 446	5.57
0.21	308 172	10.80
0.22	485 378	24.29
0.23	418 332	45.53
0.24	311 348	63.84
0.25	167 820	77.47
0.26	212 890	84.81
0.27	63 064	94.13
0.28	27 770	96.39
0.29	10 594	98.11
0.30	15 970	98.57
0.31	15 915	99.27
0.32	...	99.97
0.33	...	99.97
0.34	0 793	99.97
Totals	2284 712	

NOTE: (1) Carbon percent is on ladle analysis.
(2) Percent of steel by weight having a carbon content less than that shown in column 1.

Table 3—Percent of All ASTM A7 Plates Received During 1955 with Carbon Content Lower Than Stated Percentages

Carbon, % (1)	*Wt. of steel, tons*	*Percent having lower carbon (2)*
0.08	0 500	0.00
0.09	11 178	0.02
0.10	0 000	0.57
0.11	24 311	0.57
0.12	2 020	1.76
0.13	33 006	1.86
0.14	24 964	3.47
0.15	24 306	4.69
0.16	36 765	5.88
0.17	7 242	7.68
0.18	60 166	8.03
0.19	90 006	10.97
0.20	126 584	15.37
0.21	185 531	21.56
0.22	321 132	30.63
0.23	304 506	46.32
0.24	157 548	61.20
0.25	349 262	68.90
0.26	228 507	85.97
0.27	28 340	97.14
0.28	3 688	98.52
0.29	26 858	98.70
Totals	2046 509	

NOTE: (1) Carbon percent is on ladle analysis.
(2) Percent of steel by weight having a carbon content less than that shown in column 1.

It is believed that there is some stigma attached to using ASTM A7 for welded structures because it is not specified to be used particularly for welding, and it is not designated as a steel suitable for welding. On the other hand, it is published in the title and foreword that ASTM A373 is a suitable steel for welded structures, so it places the burden of proof on any engineer who has specified the use of ASTM A7 steel in a welded structure which subsequently fails for any reason to prove that it did not fail because the wrong steel was specified.

One important factor in the choice of steel for welded structural purposes is that steel fabricators must carry very large stocks of steel in order to avoid delays, waiting for infrequent rollings of certain sections. It would work a considerable hardship on the fabricators if it were necessary for them to carry such a stock in both ASTM A7 and ASTM A373.

After giving consideration to all the above, we decided to standardize on ASTM A7 shapes for both riveted and welded structures, but we watch the carbon content on the mill test reports and if any lot is higher than 0.30% on ladle analysis, we do not use it in welded structures. We purchase all of our plates to ASTM A283, grade C which, because of its lower specified minimum tensile strength (55,000 psi), is more suitable for welding than plates ordered to ASTM A7, and ASTM A283 is equally usable on riveted or welded structures, except as to minimum tensile strength. In the case of welded railroad or highway bridges, or other structures subject to impact, 1 in. or over in thickness, we use ASTM A373 where specifications permit. This leaves us with about the only disadvantage that we still have the stigma of using ASTM A7 shapes in welded structures, which steel is not specifically designated for welding, whereas ASTM A373, currently available, is specifically designated for welding. We think this is important, and we would like very much to avoid having to follow this practice.

Recommendations

We believe it is obvious from data included herewith that it is well within the ability of American steel mills to manufacture both plates and shapes to meet the minimum tensile strength of ASTM A7, namely 60,000 psi, and with a maximum carbon content of 0.30% on ladle analysis. It is our recommendation that the fabricating industry and the designing engineers of the country insist that specification ASTM A7 be revised to indicate in the title of the specification that it is suitable for use in either riveted or welded structures, allowing the specified 60,000-psi miminum tensile strength to remain, but adding a carbon limitation of 0.30% on ladle analysis up to a maximum permissible thickness for welded structures of 2 in. We are convinced that the mills will have no added difficulty in manufacturing steel to this specification, and that they will have very little if any increased cost, and that the cost of mill extras for this steel should be no higher than for the present ASTM A7 steel. An acceptable alternative would be

Table 4—Percent of All ASTM A7 Plates 0 to ½ in. Thick Received During 1955 with Carbon Content Lower Than Stated Percentages

Carbon, % (1)	*Wt. of steel, tons*	*Percent having lower carbon* (2)
0.08	0.500	0.00
0.09	11.178	0.07
0.10	0.000	1.59
0.11	24.311	1.59
0.12	2.020	4.91
0.13	33.006	5.19
0.14	22.244	9.69
0.15	24.306	12.72
0.16	36.765	16.03
0.17	7.242	21.04
0.18	60.166	22.03
0.19	30.512	30.24
0.20	60.426	34.40
0.21	163.569	42.64
0.22	107.675	64.95
0.23	61.276	79.63
0.24	51.364	87.99
0.25	29.578	95.00
0.26	7.097	99.03
Totals	733.237	

NOTE: (1) Carbon percent is on ladle analysis.
(2) Percent of steel by weight having a carbon content less than that shown in column 1.

Table 5—Percent of All ASTM A7 Plates Over ½ to 1 in. Thick Received During 1955 Having a Carbon Content Lower Than Stated Percentages

Carbon, % (1)	*Wt. of steel, tons*	*Percent having lower carbon* (2)
0.14	2.720	0.00
0.15		0.46
0.16		0.46
0.17		0.46
0.18		0.46
0.19	59.585	0.46
0.20	31.940	10.46
0.21	16.912	15.82
0.22	72.789	18.66
0.23	93.531	30.87
0.24	50.189	46.56
0.25	141.138	54.98
0.26	90.267	78.66
0.27	24.005	93.80
0.28		
0.29	12.975	97.83
Totals	596.051	

NOTE: (1) Carbon percent is on ladle analysis.
(2) Percent of steel by weight having a carbon content less than that shown in column 1.

that the ASTM A7 specification be revised as indicated, but that it contain in its title a statement that this steel, in thicknesses greater than 1 in., is not recommended for welded structures subject to appreciable impact.

It is believed that if the above recommendation is followed, important economies to both the producing mills and to the steel fabricators will result. The importance of having one suitable grade of steel for both riveted and welded structures cannot be overstated.

Table 6—Percent of All ASTM A7 Plates Over 1 to 1½ in. Inc. Received During 1955 Having a Carbon Content Lower Than Stated Percentages

Carbon, % (1)	*Wt. of steel, tons*	*Percent having lower carbon* (2)
0.20	34.215	0.00
0.21		9.88
0.22	28.772	9.88
0.23	105.702	18.19
0.24	11.575	48.71
0.25	96.770	52.05
0.26	51.678	80.00
0.27		94.92
0.28	3.688	94.92
0.29	13.882	95.99
Totals	346.282	

NOTE: (1) Carbon percent is on ladle analysis.
(2) Percent of steel by weight having a carbon content less than that shown in column 1.

Table 7—Percent of All ASTM A7 Plates Over 1½ in. Thick Received During 1955 Having a Carbon Content Lower Than Stated Percentages

Carbon, % (1)	*Wt. of steel, tons*	*Percent having lower carbon* (2)
0.21	5.050	0.00
0.22	111.895	1.36
0.23	43.997	31.53
0.24	44.420	43.39
0.25	81.776	55.37
0.26	79.466	77.41
0.27	4.335	98.83
Totals	370.939	

NOTE: (1) Carbon percent is on ladle analysis.
(2) Percent of steel by weight having a carbon content less than that shown in column 1.

Tables 4 to 7 show a breakdown of the A7 plates by thicknesses and indicate that, for plates under 1½ in. thick, 99.03% are less than 0.30% carbon while for heavier plates, the percentages are 97.83% for plates over 1½ to 1 in.; 95.99% for plates over 1 to 1½ in. and 98.83% for plates over 1½ in. This reversal in trend for plates over 1½ in. may be due to the emphasis on weldability inserted on purchase orders for heavy plates.

Conclusions

Based on the above data and our experience over the past thirty years in welding ASTM A7 steel, we believe the following conclusions are justified:

1. Practically all steel furnished under specification ASTM A7 from the mill supplying one fabricator is of suitable weldable quality in thicknesses up to 2 in.

2. Occasionally, some lots of ASTM A7 steel have excessive carbon which may result in underbead cracking and even in complete failure of the welded joint, particularly if the welding is done on heavy plates and in the lower range of ambient temperatures, say below 50° F.

3. There is no assurance that steel purchased to ASTM A7 specifications will be suitable for welding

because the carbon is not limited.

4. ASTM A7 steel is not the most ideal for welded structures because the steel is apt to have a high ductile-to-brittle transition temperature. As determined by the criterion of 15 lb in a standard size Charpy specimen with Vee notch, the transition temperature may be up to 100° F in occasional lots of ASTM A7 steel. This indicates that some heats of ASTM A7 steel may be unsuitable for use in welded structures subject to appreciable impact loading or to low-ambient temperatures, and that it is therefore unsuitable for highway and railway bridges.

5. The ladle analysis is what is shown on the mill test reports furnished by the mills and for steel of structural quality is made as specified in ASTM specifications A6-54T, "General Requirements for Delivery of Rolled Plates, Shapes, Steel Piling and Bars for Structural Use." If check analyses are made of coupons cut from various parts of the rolled products, carbon contents as much as 0.04% higher than the ladle analysis can occasionally be found. Thus, the maximum carbon that might be found in a member rolled to specification limiting the carbon on ladle analysis to 0.30% should be 0.34%.

6. During the past twenty years, the use of welding has increased to where it has largely supplanted riveting in some industries, i.e., the steel tank industry. During this period, the use of welding has greatly increased in the construction of buildings, and structures generally. Many thousands of structures made of A7 steel have been constructed and the percentage of weld failures attributable to excessive carbon has been practically nil. It must, therefore, be concluded that ASTM A7 steel as furnished is a suitable steel for welded structures and, if the carbon in A7 steel is limited to 0.30% by ladle analysis, the possibility of receiving material having dangerously excessive carbon is eliminated.

ASTM A373 Versus ASTM A7

Specification ASTM A373-56T, first issued in 1954, is the first ASTM specification for structural steel for welding. The principal features of this specification are that the tensile-strength range has been extended from 58 to 75,000 psi, and the carbon for plates up to 2 in. thick is limited to 0.26% by ladle analysis and to 0.30% by check analysis, while for plates over 2 in. to 4 in. the maximum carbon is one point higher, and for all weights of structural shapes the carbon maximum on check analysis may go as high as 0.32%. In general, the intent of the specification is to provide the required tensile strength with manganese instead of carbon in thicknesses over $^1/_2$ in. and in the case of plates, to secure lower transition temperatures by specifying a minimum permissible silicon content. The large tensile range permits a considerable variation in the strength of the steel, which may be undesirable.

Specification ASTM A373 permits a minimum tensile strength of 58,000 psi and does not conform to the present American Institute of Steel Construction specifications which require a minimum tensile strength of 60,000 psi. This prevents the use of this (A373) specification on all structures designed to comply with the AISC specifications.

On the basis of present mill extras, ASTM A373 plates up to $^1/_2$ in. in thickness carry an extra 5¢ per cwt. or $1.00 per ton over ASTM A7. Plates over $^1/_2$ in. to 1 in. cost 25¢ per cwt. or $5.00 per ton over ASTM A7. Plates over 1 to $1^1/_2$ in. cost 90¢ per cwt., or $18.00 per ton more than ASTM A7, and plates over $1^1/_2$ in. to 2 in. in thickness cost 25¢ per cwt., or $5.00 per ton more than ASTM A7. The price differential for shapes rolled to ASTM A373 is 35¢ per cwt., or $7.00 per ton for shapes in Group A and 15¢ per cwt. or $3.00 per ton for shapes not in Group A, as compared with ASTM A7. Thus, ASTM A373 represents a considerably increased cost over ASTM A7, particularly in thicknesses between 1 and $1^1/_2$ in. This is due mainly to the required silicon killing.

It must be emphasized that ASTM A373-56T is a more suitable steel for welding than ASTM A7-56T, in all thicknesses, and particularly in thicknesses over 1 in., mainly because of improved low-temperature impact properties. It is questionable whether ASTM A373 is any better or appreciably any different than ASTM A7 *as received* for the entire range of shapes and bars.

DISCUSSION BY NATHAN W. MORGAN

The author brings out many interesting and valuable data concerning the weldability of ASTM-A373 and A7 steels. It is believed that this paper will invoke considerable discussion on this currently important topic. For the sake of brevity, the writer will mention a few criticisms of the author's paper.

The two opening sentences of the abstract appear to be in error since the reference should be either to A373 steel rather than A7, or if all kinds of structures are covered, to both A373 and A7 steels. The author's principal argument appears to be that A7 steel is almost equivalent to A373 in weldability since the carbon content is usually satisfactory. He then recommends a revision to the A7 specification to bring it within an assumed proper range of weldability, but without mentioning minimum requirements for either manganese or silicon.

The principal argument has been presented many times both before and since the promulgation of A373,

Nathan W. Morgan, Bridge Engineer, Bureau of Public Roads, Washington, D. C.

The trouble has always been that the data presented is never broad enough. There is much A7 steel that does not meet the chemical requirements of A373. The carbon content may be as great as 0.35% ladle analysis. The writer has before him a current welded bridge project in which A7 steel was wrongly substituted for A373 steel. Of the meager information at hand, for 10 items of plates 1 to 1½ in. thick, 40% do not pass the A373 requirements for carbon and 70% fail to meet the requirements for manganese and 100% fail to meet the requirements for silicon.

The writer concurs with the author's conclusions numbers 2, 3, and 4, but conclusion number 1 leaves one guessing as to what "suitable weldable quality" would mean, in the light of the vast amount of welding research accomplished in the past few years. The writer could concur with the author's final recommendation for limiting the carbon content of A7 steel to 0.30% by check analysis for thicknesses up to 2 in. providing minimum manganese and silicon were included, but it is doubtful that the manufacturers will agree. This would include the heaviest 36-in. deep beams. The question then would concern a specification to cover flange plates over 2 in. thick for welded girders.

The author objects to A373 because it does not have the required tensile strength for the AISC specification by which he evidently means A7, yet he purchases all plate material under A283 grade C which has only 30,000 minimum yield strength. Therefore, he must have no plates in stock to meet A373. Moreover, he must stock plates and shapes for statically loaded welded structures as distinguished from dynamically loaded structures. The allowable working stress for the one case is about 16,200 psi and for A373 steel it is basically 18,000 psi.

My discussion covers the failure of the author to give proper consideration to scientific weldability in his proposal. This was discussed years ago by the AWS Bridge Committee and a mass of scientific investigations and reports have supported the early opinions that the carbon content needed to be as close to 0.25% max as practicable, ladle analysis, and that manganese and silicon are of equal importance. This resulted in the promulgation and adoption of the A373 specification. If any economy would result from the use of a single steel specification for both riveted and welded structures for both static and dynamic loadings, I believe that specification should be ASTM-A373. The author's recommendation to modify A7 specification to limit the carbon to 0.30% ladle and the thickness to 2 in., is an inadequate control for welding.

DISCUSSION BY JOHN E. SOUTH

The paper would lead the uninformed reader to believe that, since such a small percentage of A7 steel has a carbon content higher than desirable for welded structures, it should be a simple matter to get the producers to agree to guarantee that all steel meeting A7 specifications would meet all welding requirements.

Those who have held many meetings with the representatives of steel producers know that this cannot be done, and that the only alternative is a new specification.

The paper gives tables showing the different percentages of steel meeting certain carbon contents. This steel, presumably, is that received by one fabrication and no mention is made of the number of suppliers. Perhaps if all suppliers of base steel were included, the results would have been quite different.

Engineers in general agree that most of the A7 steel is suitable for welding. It is necessary that precautions be taken to see that the small percentage of unsuitable steel is not incorporated in dynamically loaded structures.

Steel not satisfactory for welding can be produced under A7 specifications and this is especially so in the thicker material. It is to guard against the use of this small percentage of material that the ASTM-A373 specification was adopted.

John E. South is Assistant Chief Engineer, Eastern Region, Pennsylvania Railroad Co., Philadelphia, Pa.

DISCUSSION BY HENRY J. STETINA

Mr. Jackson, possessed with extensive practical experience indicating careful control of production procedures, has ably presented the case for the desirability of a common structural grade of carbon steel that will satisfy all types of riveted and welded construction.

It is interesting to note that Mr. Jackson arrived at his justification for an improved steel specification through a more liberal acceptance of carbon content than is to be found in technical works of researchers and metallurgists. Whereas Mr. Jackson accepts for ordinary welding steel material having up to 0.30% carbon by ladle analysis, most authorities would prefer to limit carbon to about 0.26% on the ladle (equivalent to 0.30% check) with the extremists

Henry J. Stetina is Regional Engineer, American Institute of Steel Construction, Inc., Philadelphia, Pa.

clamoring for limits of about 0.21%. It is to be observed that A373 steel has a maximum carbon limit of 0.27% ladle analysis for plates, 0.28% for shapes. This specification, at the best, was but a compromise solution, applauded by the majority, but still criticized by the extremists mentioned above.

Specification ASTM-A7 has been criticized for the past two decades, not so much as to the material as rolled or because of unsatisfactory usage, but rather because the specification is open ended, i.e., no chemistry control of the carbon or manganese contents. Consequently, the critics say there is no assurance as to its weldability, either for fabrication or for service. Fortunately, as indicated by Mr. Jackson's records, and further attested to by the thousands of welded structures now in service, the bulk of A7 steel has been generally satisfactory. However, since there is that possibility of high-carbon steel with low notch toughness having been used, even though satisfactorily welded, the critics have questioned possible infringement of assumed safety factors.

Mr. Jackson rejects A7 steel for welded structures subjected to appreciable impact loads or to low ambient temperatures, giving as examples highway and railway bridges. It should be noted that the Society's Standard Specification for Welded Highway and Railway Bridges, revised in 1956, also rejected A7 steel by adopting ASTM-A373 steel for all stressed parts. Other specification authorities covering this class of structures have also followed suit so that now there is uniform base material requirements for welded bridge construction in this country.

This rejection of A7 steel specification could well be extended to certain stressed parts of the so-called statically loaded buildings where assured notch toughness of base material is equally desirable even with lesser impact or with moderate temperatures. As engineering design moves forward, bringing with it new record clear span construction, e.g., welded rigid frames, continuous beam and girder framing in ever taller buildings, rigid vierendeel trusses, and thick flange girders, all of welded design and based upon the latest refined theories that determine the size of each section, then it becomes logical that requirements for improved base material be advanced in the same forward direction if true and complete progress is to be attained. One modern development in structural design, probably the most radical concept since the birth of elastic theories, is that known as "plastic analysis." At the moment, this method is particularly suited for determining the section of the foregoing types of continuous structures and promises to result in more economical sections. Although this method is workable with A7 steel, it becomes apparent that base materials possessing assured notch-tough characteristics would be most welcome.

While we habitually associate notch toughness with weldability, thereby creating a false cleavage between riveted and welded construction, we should correct this impression by acknowledging the fact that notch toughness in base material is beneficial to all types of structures whether they be riveted, bolted or welded. Failures in certain types of riveted structures such as ships by the brittle fracture mode has been well documented although probably not so well publicized as similar brittle fractures in welded structures. Admittedly, the very nature of monolithic construction, inherent with welding, has brought the brittle fracture problem, with accompanying demand for assured high notch toughness, into sharper focus. Therefore, a common structural steel for all usage is very much in order as the author recommends.

Notch toughness, as a property of steel, is not generally understood by structural engineers, perhaps because of the apparent general, successful use of present materials. One area of confusion has been the lack of differentiation between weldability for fabrication and weldability for service. A clear concept of this distinction is given in "Weldability of Steels" published by the Welding Research Council.

At the moment, Mr. Jackson is correct in stating that A373 steel is not technically acceptable wherever the AISC specification governs. The technicality is the slightly lower theoretical factor of safety as measured by the minimum yield points of the two steels: 33,000 psi for A7 steel, 32,000 psi for A373 steel. This difference or lack of recognition is more of an awkward and temporary condition rather than a serious handicap.

The AWS Committee on Building codes, on which the writer has served as chairman for the past six years, is presently considering a partial adoption of A373 steel, perhaps for the thicker rolled-plate material used for the rigid types of framing and for heavy flanges of built-up girders. To be more specific, the Committee has recently recommended that for steel up to 4 in. in thickness, A7 steel would be allowed for all structural shapes, regardless of thickness, and for all plates up to 1½ in. thickness except that in rigid frame construction A7 steel would be used only up to 1 in. thickness. Plates over 1 inch thick in rigid-frame construction and over 1½ in. thick in simple or semi-rigid type construction would be required to use A373 steel. Such revised provisions, of course, will be reflected in the next edition of the Society's "Standard Code for Arc and Gas Welding in Building Construction." One member of this Committee, referring to this action, has sagely observed: "should carry thru what I call a transition period as the time will soon come when everyone can agree on permitting A373 material for all thicknesses of material for welded construction."

It is understood that the AISC is likewise considering the problem; possibly will accept the recommendations of the Committee on Building Codes. Therefore, the obstacle of code regulations in the building field may soon be rectified in much the same manner as now in evidence for bridges.

While Mr. Jackson has mentioned this situation as it may pertain to A373 steel, he states that his com-

pany purchases all plates to still another steel, A283 grade C. This steel is not recognized by the AISC specification or by either the Society's bridge or building regulations. It is not clear under what conditions this steel specification has been used for structural applications.

Furthermore, there would be considerably more objection to using A283 steel than A373 because A283 grade C has a minimum yield point of but 30,000 psi. Naturally, the lower strength of A283 suggests lower carbon and consequently improved welding characteristics. But in the final analysis, A283 specification does not limit carbon and therefore is subject to the same criticism as afflicts the A7 specification.

This serves as an example of the further confusion that may enter this picture, when there is no commonly accepted and available standard specification for steel to be used for both welded and riveted structures, and therefore, each user bases his requirements upon his individual experience and practice. Mr. Jackson makes a definite point of selecting steel most suitable for welding, a procedure that is voluntary. Some fabricators may find his method a hardship, particularly when steel is cut to length at the mill, being carmarked for a specific project, and arrives at the shop ready for immediate fabrication in order to make a prompt delivery date; then the practice of selectivity at the fabricators' plant could be too late and generally impractical. Assurance of good weldability should start at the mill—the basic reason for introducing A373 specification.

It is somewhat unfortunate that the author's data, covering one year of actual production, is rather meager in the thicker ranges of rolled-steel material. Most all of the discussion within the AWS Committee on Building Codes has concerned the suitability and requirements of base material whose thickness exceeds $1\frac{1}{2}$ in. Since carbon generally increases with thickness up to about 4-in. thick material, the problem of weldability is more apt to be centered on materials whose thickness range from $1\frac{1}{2}$ in. to about 4 in. thick. More data in this thickness range would be enlightening although not necessary for writing suitable code regulations at this time.

This entire subject has provoked considerable controversy. An analysis of the most vociferous protests directed towards the adoption and usage of an improved steel specification fails to reveal any serious objection to the technical soundness of controlling carbon and manganese. Objections can all be traced to two facts (1) extra mill costs for controlling chemistry, (2) handling of two steels, instead of one universal common steel. Were it possible to revise A7 steel by merging it with A373, as implied by Mr. Jackson, and without increasing cost because of the millions of tons involved, there would be no controversy.

DISCUSSION BY VAN RENSSELAER P. SAXE

In commenting on Mr. Jackson's article, I would like to make the following observations:

I believe that he is writing about the effect of butt or groove welding on heavy thicknesses of A7 steel and not referring to other types of welding such as fillet, etc.

He also points out that the attempts to bring into the market such steels as A283 and A373 to secure steels of supposed better welding quality have resulted in serious delays in getting either of these grades, and shops are being obliged to stock these grades to have them on hand at least in sufficient quantity to get a job started.

One result of this attempt to introduce these new steels, aside from the points he brings up of greater original cost, less tensile value in A283, etc., is that shops using these steels must be delayed in production of weldments due to the necessity of teaching their operators different procedures required for welding these steels than those the men were familiar with in using A7 steel.

Another most definite draw-back is that in much bridge plate girder work where, under certain specifications, the use of these steels is obligatory, because of these delays, greater cost of finished product, etc. many State authorities are going to prestressed reinforced girder bridges and, in fact, many private engineers, under the efforts of the various trade groups, are using this same device for long span work in building construction, all of which conditions do not help the structural rolling industry or the shops fabricating their material.

All of these efforts to downgrade A7 as a weldable material are creating a suspicion in the minds of design engineers, not too familiar with welding, that they are doing something hazardous when they use A7, which, as Mr. Jackson, points out, is not the case, as a result of the shop experience he so carefully analyzed. I might add that I wish he had underscored the words "is usually suitable for welding" contained in the second sentence under "Abstract" for this would better emphasize his later statements and conclusions.

I see no reason to object to trying to get a better steel which would show better workability for both riveting and welding, but I have felt for several years that those people who were so zealous about promoting new steels several years back would have done a more business-like and satisfactory job if they had worked with

Van Rensselaer P. Saxe is Consulting Engineer, Baltimore, Md.

the mills to modify A7 steel specifications so that it would serve the purposes required and thereby not clutter the mills with a lot of miscellaneous steels which, quite naturally, they can only roll once in a while, thereby causing delays in securing these new materials with its consequent added costs, because this material must be worked in with the presently large tonnages of A7 being rolled. It would seem that the mills and everyone else would be better off with one steel which could be used satisfactorily for welding and riveting and which could be secured, as Mr. Jackson points out, by the comparatively easy process of limiting carbon to 0.30%, which most of the mills now seem to do, in spite of the fact there is presently no limitation in the A7 specification.

About three years ago, when this agitation about A7 steel not being a good weldable quality first started and began to come into more or less public notice, I was quite puzzled, for in the period starting in 1926 to the present, our office had designed and supervised construction of close to 2000 all-welded structures of every type and we had never had a failure. I actually was beginning to think I better start "knocking on wood," for all of this work had been furnished from many different rolling mills and fabricated by many more different fabricating shops, many of which did their first welded work under our supervision and help.

These structures included many heavy butt-welded trusses, very heavy butt-welded plate girders—many of these girders have 4½-in. thick butt welded cover plates—and the usual run of the heaviest rolled sections.

In view of this condition with which I was familiar, I decided to make an investigation of our mill inspection reports covering the A7 steel used in our work, for we, through the years, have had these reports on all of our work and I found that in no case, except some very light beam work, did the mill reports show that the A7 steel ever ran even as high as 0.30%.

While we, in our specifications, have never specified anything but A7 steel as rolled, one of two things could have happened—either the mill just naturally furnished A7 with less than 0.30% carbon or the shop may have asked them to hold the carbon range, but this surmise could not hold in the early days of welding, for no one ever questioned the weldability of A7 steel, which questioning is only of comparatively recent vintage.

Having satisfied myself that all of our work was within a reasonable carbon range, I then decided it might be well to contact other fabricators, inspection companies, etc., to try to find if they had ever experienced failure in A7 steel, for, in my travels around the country, I had the pleasure of meeting many of these men active in the welding end of their business and felt I could, through this process, get honest answers to my request, for if there is one field in which you can receive such answers, it is in welding, where everyone is definitely interested in improving material and methods and do not hold it as a secret if they find a better process or procedure.

I wrote a similar letter to forty people located all over this country from East to Pacific Coast and south to Florida and Texas. In this letter, I explained my reasons for writing, in that I heard there had been allegations of failures of butt welded A7 plates, especially heavy plates, which I could not understand, in view of our experience through the years. I also asked if they were having better experience with the proposed new steels which we had never used or specified, and what was their attitude on restricting use of A7 in the heavier plate thicknesses. As I remember, 34 letters were received in answer to my inquiry. Not one of the fabricators had ever had a failure of A7 steel and some of them had butt welded plates up to 6 in. and 9 in. thick, some of it for work under heavy impact and vibration loading. Many explained that the procedures for handling A7 steel were so well known by their shop men that they never expected to have any failures. Many complained that using the new steels they had been obliged to train their men for new procedures and all complained that the use of so many steel types was causing great additional expense due to stock, training required, etc, a point well covered by Mr. Jackson and one of the welding engineer's most vigorous in his efforts to place restriction on the thickness of A7 which could be butt welded admitted that, in spite of the fact they had done very thick butt-welded plate work using A7 steel, he knew of no failure of the work in use.

As I remember, one fabricator's chief engineer thought that A7 should be limited to 2 in. thickness when butt welded, though he stated he knew of no failure of butt-welded plate work done by his firm in which A7 was used.

The result of all of this investigation has convinced me that, in spite of what is being said, A7 still remains a safe steel to weld, so I will keep on using A7, for it will be no penalty to ask the mill to hold the carbon range for the comparatively small amount of heavy plate work used for butt welding. On the other hand, I am definitely in agreement with Mr. Jackson that something should be done and an effort made, either through the ASTM or the mills, to get the mills to agree to a limit of carbon to 0.30% in A7 steel to make all A7 steel a weldable and rivetable steel and it should be so stated as a part of basic A7 specifications revisions, as suggested by Mr. Jackson.

As Mr. Jackson suggests, such an action would not be difficult for the mills. In fact, I would think it would save them a lot of trouble and expense to be able to roll one type of steel which would be better for welding and riveting, than to be subject to the demand for rolling the various steels now required for welding or riveting, when one steel will do the trick, for I suppose shortly some one will be demanding a structural steel which will have known value to resist the compression stress in beam webs where washers for high-tensile bolts are used, for one must admit that these webs must stand a severe compression for long periods of time.

The suggestion made by Mr. Jackson should be

given serious consideration, so let's get started doing something about it.

It seems to me that the American Welding Society is one organization which might start the ball rolling, for I am sure it could secure plenty of cooperation from other interested sources, so who knows but that it might. An A7 - 58 specification could contain a much needed revision and Mr. Jackson is to be thanked for bringing to light a suggestion for action long kept on the ice, for, as he suggests, I am sure the mills will cooperate.

AUTHOR'S CLOSURE

Mr. Morgan, in his second paragraph, indicates that the two opening sentences of the abstract appear to be in error. While it was not specifically stated in the abstract, it was brought out in the paper that the only available steel for both riveted and welded structures is ASTM A7. A373 is not acceptable under the AISC specification because it does not have the required tensile strength.

With reference to the minimum requirements for either manganese or silicon, it is my contention that since ASTM A7 has been satisfactory for welding in the past, no change to the specification with reference to manganese and silicon need be made. Mr. Morgan is entirely correct in stating that there is much A7 steel that does not meet the chemical requirements of A373. It is my opinion that it is not necessary for steel for welded static structures to meet the requirements of A373, and if the carbon content is limited as recommended to 0.30% by ladle analysis, past history indicates that the steel will be suitable for welded static structures. It is admitted that A373 should be specified for welded bridges and it is our opinion that it would be wrong to substitute A7 where A373 is specified. Again in the last paragraph, the writer is referring to welding suitable for static structures and not to dynamically loaded ones, such as highway bridges.

With reference to Mr. South's comments, I do not believe it would be a simple matter to get the mills to guarantee that all steel meeting A7 specifications would meet all welding requirements. I do believe that if the mills would agree to modify the A7 specification to limit the carbon to 0.30% on ladle analysis that the steel furnished would be suitable for welded buildings and other welded statically-loaded structures. Mr. South is entirely correct that the tables represent only one fabricator's experience, but it is my position that this supplier has consistently furnished steel to the A7 specification with over 99% of it having less than 0.30% carbon on ladle analysis and all suppliers should be able to do likewise. In reply to the fourth paragraph, the precaution which I recommend is that the A7 specification be modified to limit the carbon to 0.30% on ladle analysis, and I would recommend that the thickness be limited to 2 in. to avoid the difficulty of meeting the carbon maximum and the minimum tensile strength.

Mr. Stetina, in his second paragraph, notes that I arrived at a justification for an improved steel specification through a more liberal acceptance of carbon content than is to be found in technical works of researchers and metallurgists. This is true, but it must be explained that the maximum carbon limitation, 0.30% by ladle analysis, does not represent any compromise, since it is recommended only for statically loaded structures, and since ASTM A7 steel has been furnished for many years for such structures, with few, if any, occurrences where weld failures have been directly chargeable to excessive carbon. The maximum carbon content of ASTM A7 steel up to 2 inches in thickness, rarely exceeds 0.30% by ladle analysis. My purpose is to eliminate the possibility of receiving lots with carbon higher than 0.30%, so that the success we have had in the past can be assured in the future. A373 steel is a superior steel for structures having large dynamic loadings, and should be used in such structures.

I agree with Mr. Stetina's comments regarding the need for more uniform steel for the construction of welded rigid frames and other modern designs than it is now possible to receive under the so-called "open ended" ASTM A7 specification, but I can see no need for a steel of greater notch toughness in a riveted or welded rigid frame than in a welded or riveted hangar stressed only in tension, but for purely compressive loads, such as short length columns, the physical properties of steel have much less significance with respect to its performance. However, in "plastic design" where there must be a definite (but small) change in length of members to bring about the assumed load distribution, it seems to me it is more important that the steel have definite ductile characteristics. ASTM A7- being a soft (non-hardened) steel, has definite ductile characteristics and, therefore, seems as suitable for plastically designed structures as, for example, A373. It seems to me the only advantage of A373 over A7 is that it has a lower transition temperature and should, therefore, withstand more severe or more frequent or lower temperature impact loading than A7, and, also, that due to its lower specified carbon content, if it is actually received with a lower carbon content than A7, it should be more easily weldable. However, this difference is slight, and modern welding techniques, such as low-hydrogen electrodes and preheating, can easily overcome this difference. It must, therefore, be emphasized that the nature of the loading on the structure is the important

criterion which determines the type of steel which should be used and for moderate temperature exposures and moderate impact intensities, which conditions probably cover a very appreciable percentage of all steel structures being built today, a steel such as ASTM A7, restricted to 0.30% ladle analysis, is admirably suitable for either riveted or welded structures, and should certainly have an important place in our available steel materials, as should also A373 for structures having lower working temperatures and higher intensities of impact loading.

It will be some years before the exact temperature levels and impact intensities for the different steels are even approximately determined, as only experience provides the answer, and that comes very slowly.

The specification A283-C is generally used for tank construction and does not meet the tensile requirements of the AISC specification. There is very little practical difference in plates received under either A7 or A283-C and many engineers feel that a higher factor of safety results from the use of a slightly more ductile material, which should result from a lower maximum yield strength specification.

With reference to Mr. Saxe's comments, I do not see where the use of fillet as compared with butt joints has any great bearing on the question of steel's suitability. It is my understanding that if a steel is weldable, it is equally weldable using either fillet or butt joints. Of course, it is extremely important that the right type of joint be used, and butt joint construction is obviously more resistant to impact and low temperature loading, regardless of the type of steel.

Mr. Saxe's comments with regard to delays occasioned by specifying the use of special steels, such as A373, where it is not really needed, are very well founded. In making the weldments for a large structure, many small parts are needed. It is not the practice to order such detail for each job, as it has been found more economical to carry a stock of plates and shapes from which it may be cut. Much confusion would result from several specifications for this detail material, and it can be readily seen that the inventory would be greatly increased, all of which is very undesirable unless compensating improved results are obtained. It is my belief that for the very large percentage of welded steel structures, the compounding of utility inventories is not justified and no appreciable, worthwhile improved results can be demonstrated.

Mr. Saxe's statement that since 1926 their firm has supervised the design and construction of close to 2000 all-welded structures of every type using A7 steel, and that they have not had a single failure, is of the utmost importance. This represents the experience of one firm. There are many hundreds of similar firms with similar experiences, and in view of this background, it would appear to be unwise to discontinue its use. I do not contend that A373 is not as suitable a steel as A7 for general steel construction, but I do want to emphasize that there is nothing in the background of the use of A7 which would indicate the necessity for any change except, perhaps, the possibility of receiving a lot of steel with excessive carbon. If this defect can be corrected, and the fine record of A7 in the past in both riveted and welded structures can be continued into the future, and the objective of a single steel for both riveted and welded statically loaded structures can be attained, it would seem to me that an ideal solution to this problem will have been reached, with no increase in cost for the large percentage of statically loaded structures. It is desirable to have a suitable material such as A373 available for structures having lower working temperatures or greater impact loadings. Future experience will locate more exactly the types of structures and intensities of loading where the more notch-resistant types of steel should be used.

I wish to thank those who have spent much time in analyzing and commenting on this article.

Who's Who?

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STUD SHEAR CONNECTORS HELP TO SPEED BRIDGE CONSTRUCTION

Through use of stud shear connectors, end welded in the field, the shear developers for decks of composite steel-and-concrete bridges in Michigan are being erected at least 25% faster than formerly (Fig. 1).

In the first use by the Michigan state highway department of studs as shear connectors, approximately 8500 headed studs, $\frac{3}{4}$ in. diam by 4 in. long, were end welded recently to the beams of a bridge just completed at Farmington. The studs bond the steel beams and concrete slab together so that they act as a unit and reduce the amount of structural required in the bridge.

Results at Farmington were so satisfactory that stud shear connectors are now being specified for several future composite bridges in Michigan. On the Farmington job, the contractor elected to use studs rather than welded spirals that were specified as an alternate.

Besides being easier and faster to install than other shear connectors, the field-welded studs simplified the placement of reinforcing steel. Forms were erected between the girders before studs were applied.

Average speed for each of two operators using stud welding guns was four studs per minute, although the rate occasionally was six or seven studs per minute. The Bodrie Welding Co. of Detroit used two 500-amp welders, hooked up in parallel and driven by 300-hp gasoline engines, to supply the 1200-amp current needed for welding the large-diameter studs.

Studs were end welded in rows of four on approximately 3-in. centers across the flanges of the bridge girders. Rows were 15 in. apart on girders at both ends of the bridge and 18 in. apart in the center girders. The Farmington bridge included three 53-ft long spans, each span having nine girders. Approximately 2750 studs were welded on each span.

To simplify placement of studs, helpers preceded the gun operators, first marking projected stud rows with chalk and then placing porcelain ferrules in the proper stud locations along the rows (Fig. 2). After placing a stud in the gun, the operator then simply pressed the stud into the ferrule and squeezed the trigger for a weld. The ferrules confined the molten metal of the weld area.

Based on a story by Nelson Stud Welding Division of Gregory Industries Inc., Lorain, Ohio.

Fig. 1 These headed stud shear connectors, end welded in the field, permitted the shear developers for concrete decks on a composite bridge at Farmington, Mich., to be attached 25% faster than formerly

Fig. 2 With this stud-welding gun, approximately 8500 headed shear connector studs, $\frac{3}{4}$ in. in diameter and 4 in. long, were end welded recently to a composite bridge at Farmington, Mich. Helpers preceded the operators, marking the projected rows of studs with chalk and then placing porcelain ferrules in the proper locations

HARD-SURFACED SPUR GEARS LAST 35 TIMES AS LONG

An amazing statistic—an improvement of over 3400% in gear life through hard surfacing—has been disclosed by a prominent midwestern manufacturer. The gear in question is used in a ball mill operation (Fig. 1). The hard-surfacing material responsible for this remarkable improvement in the wearing qualities of the spur gear is an iron-base electrode containing chromium, molybdenum, silicon and carbon.

The ball mill is used to process various metallic compounds that contain extremely abrasive ingredients. In the process of reducing the particle size, metallic dust emanates from the rotating ball mill and settles on the driving gears. This condition decidedly complicates the problem of gear wear.

The pinion gear is fabricated of hardened steel and, being small in size, it resists fairly well the abrasion of the metallic dust deposits (Fig. 2). Original equipment spur gears, however, are too large to permit economically making them of the same material. To hold cost down while providing wear-resistant qualities suitable for normal service conditions, the ball-mill manufacturer produces the spur gears of a special high-grade cast iron. The new gears have cast, unmachined tooth surfaces.

When first installed, the spur gear operated but 80 hr before being worn to the point of uselessness. It was at first assumed that the gear was either the product of an unsound casting or out of tolerance in some way. Another gear was ordered and installed with approximately the same result. In all, a total of four original equipment replacement spur gears were tried with similar results in every case. No gear lasted longer than 140 hr in this service.

At this point, it was decided to try hard surfacing the spur gear on the wearing face of each tooth. The result was a gear that, after 1760 hr of operation under identical conditions, showed no visible signs of wear. Based on performance to date, it was anticipated that total gear life would exceed 5000 hr. The hard-surfaced gear, therefore, will outlast more than 35 unprotected parts. Another remarkable fact is that reclamation of a worn gear by hard surfacing is less costly than purchase of a new gear.

The electrode was applied by d-c arc welding to the wearing face of each spur gear tooth (Fig. 3). The deposit was laid in a series of beads approximately $\frac{1}{8}$ in. thick using a $\frac{3}{16}$-in. diam electrode. Following welding, the deposit was ground smooth using hand equipment. The gear was then ready for installation.

Based on a story by the Wall Colmonoy Corp., Detroit, Mich.

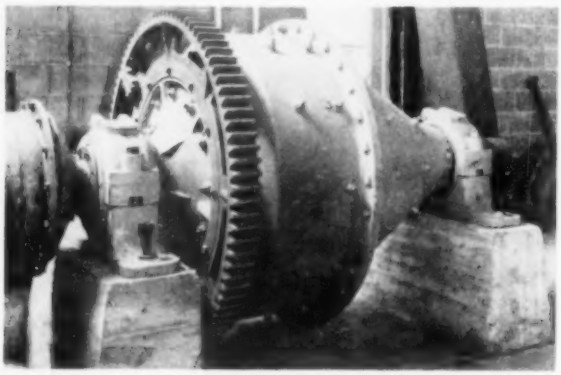

Fig. 1 Hard-surfaced gear in place on ball mill

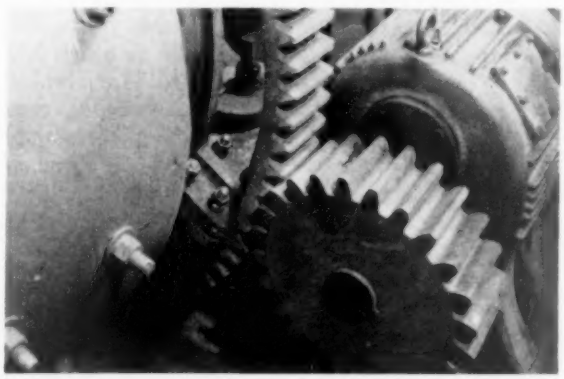

Fig. 2 Close-up showing steel pinion gear meshed with hard-surfaced spur gear

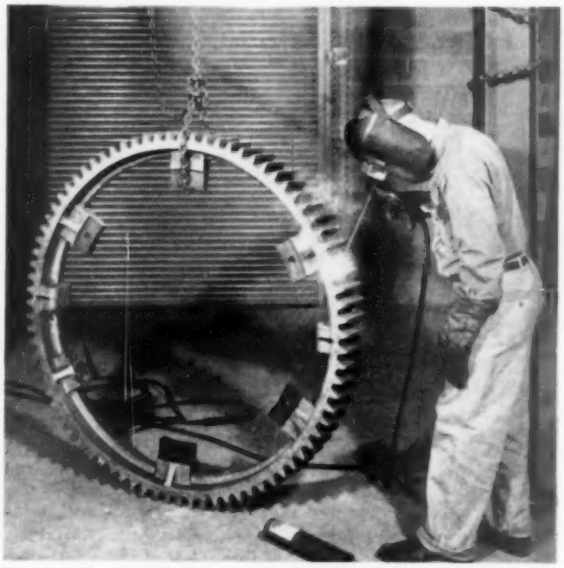

Fig. 3 Hard surfacing a worn spur gear by arc welding

UPSTAIRS WITH INERT-GAS METAL-ARC WELDING

The welding operators in the Berlin Chapman Co. of Wisconsin actually move "upstairs" to watch inert-gas metal-arc welding do its job. The assembly of "mixing conveyor heat exchangers" required the welding of stainless-steel flight sections spirally around twenty-foot long hubs. Looking for the best way to weld the flights, the engineers decided to move the operation "up" instead of "out". This break with convention is an obvious success and the construction of the complicated flight sections moves along without a hitch.

The operation starts in conventional on-the-ground activity. The hub is placed horizontally so that the flight sections can be properly positioned (see Fig. 2). After the sections are tack-welded into place the first inert-gas metal-arc weld is ready to go to work. The hub is placed on an angle parallel to the stairs so that

Based on a story by the Linde Co., New York, N. Y.

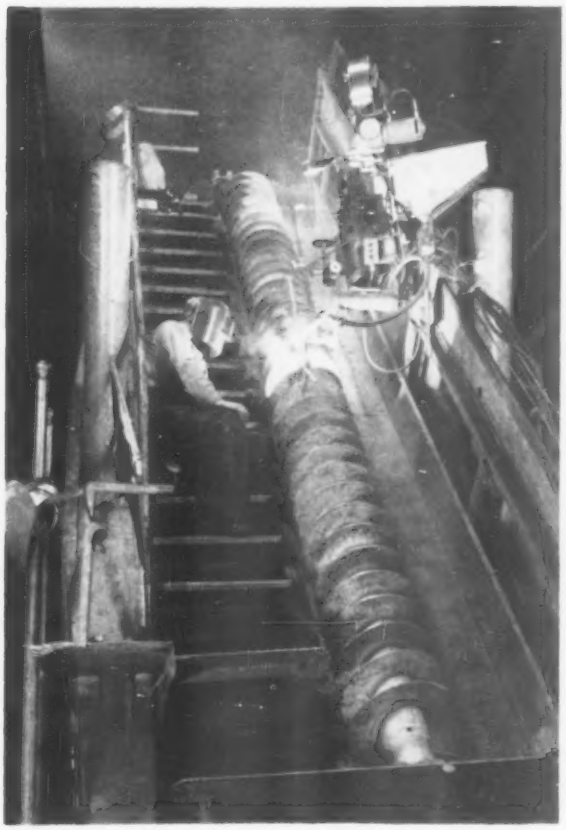

Fig. 1 Welding operator moving "upstairs" to watch inert-gas metal-arc welding of mixing-conveyor heat exchanger

Fig. 2 Still on the ground. An electric-welding operator positions flight sections on the hub. The first automatic weld is between the base of the sections and the hub

Fig. 3 Two half-flight sections are now welded together at the edge of the screw. This is the second of three welds. The last weld joins the second half-flight to the hub. All welds run continuously the length of the hub

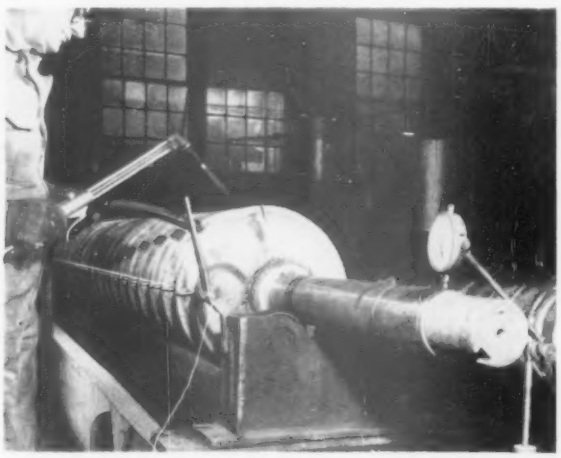

Fig. 4 The completed screw gets some finishing touches on the inspection jig. Any distortion is cleared up by oxy-acetylene heating followed by water quenching

Fig. 5 Here is the completed product. When the lid of the container is secured, the machine will be capable of countless mixing and temperature-control jobs

the working surface of the screws assumes a horizontal position shown in Fig. 3. The positioning fixture of the mechanized welder moves up or down while the hub is rotated. The speed of the carriage corresponds exactly with the pitch of the flight screw, enabling each weld to move continuously the length of the hub.

The initial inert-gas metal-arc weld is between the first half-flight section and the hub. The other half segments of the conveyor flights are then placed around the hub and tack-welded. The second pass of the automatic welder holds together the two half segments at the outer edge of the screw. The final automatic weld attaches the second half of the conveyor flights to the hub. The screws are then brought back to a horizontal position and placed on an inspection jig. Any small kinks in the flights are removed as shown in Fig. 4 by locally heating the distorted area with an oxyacetylene torch followed immediately by water quenching.

The time needed to complete each hub is between six and seven hours. This includes positioning, butt welding, three automatic inert-gas metal-arc welds and a corrective inspection. The total welding required on each twenty-foot screw is 364 linear ft at an operating speed of approximately 12 ipm.

When the screws are mounted, four each, in the finished unit (see Fig. 5) they are capable of a variety of functions. They can heat or cool, as well as mix, anything from grain to chemicals and ore. The mixing is accomplished by the intermeshing of the flight screws. The temperature is controlled by a liquid that flows through small openings from the hubs into the hollow conveyor flights.

The advantages of inert-gas metal-arc welding are apparent in this operation. Argon gas shields the welds from possible contamination by air and at the same time eliminates the need for flux. The welds are of a quality that holds finishing and cleaning costs to a minimum. The coiled-wire electrode allows continuous welding once a pass is started. And the speed available through the rapid rate of heat input shortens the job. Other savings are found in the lack of stub loss, high deposition rates and minimum spatter loss.

SPECIAL ARC-WELDING TECHNIQUE IMPROVES SHELL PRODUCTION

Automatic arc welding of rotating bands to artillery shells has cut production costs of shells produced for Frankford Arsenal in Philadelphia, Pa. (Fig. 1). Increased accuracy and safety of artillery weapons has also resulted from the adoption of this new method.

Two special arc welders, using the new technique, produce 30-mm shells at a rate of 400 per hr and 105-mm projectiles at a rate of 54 per hr. These welding machines are both equipped with a loading chute and an unloading mechanism and perform the entire operation automatically. The operator pushes a start button once and then keeps the loading chute full of shells.

Munitions manufacturers formerly machined a groove in thick-walled shells and swaged the copper rotating band in place. The rotating band engages rifling grooves in the barrel of the artillery piece in order to seal in gases and spin the projectiles.

In the newer process, the two arc welders deposit a copper band on the smooth surface of the shell. This permits fabricating the shell with a thinner wall, reduces machine operations and eliminates all operations

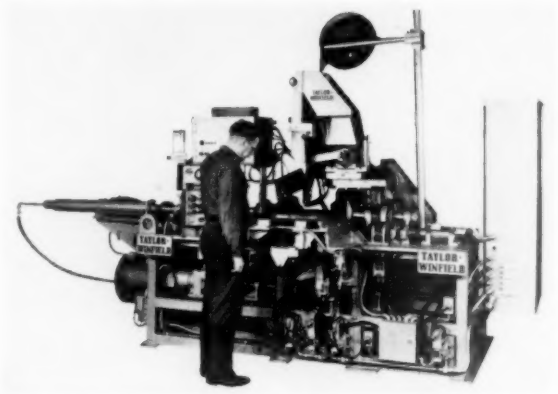

Fig. 1 Automatic arc welding of copper rotating band to artillery shell

formerly required to make the preformed rotating band. The new method also saves copper, since none is needed for bedding in the groove.

The welded copper bands do not spin off when the shell is fired. This increases firing accuracy and reduces safety hazard to military personnel.

Based on the story by The Taylor-Winfield Corp., Warren, Ohio.

Society News

Technical Papers Program Formulated for 1958 National Spring Meeting in St. Louis

ASME Metals Engineering Division to Sponsor 4 Sessions

The 1958 AWS National Spring Meeting will be held on April 14–18 at the Hotel Statler in St. Louis, Mo. Twenty-one sessions have been scheduled—four of these will be sponsored by the ASME Metals Engineering Division Conference.

Included among the AWS-sponsored sessions will be two each on resistance welding, brazing and gas-shielded welding. In addition, there will be 3 sessions on steel weldability and research, while single sessions are scheduled for titanium; aluminum and magnesium; uranium, titanium and high-nickel alloys; submerged-arc welding; application, equipment and inspection; welding arcs and heat flow; welded structures; and designing for welding.

The ASME will co-sponsor sessions on strength of welds; mating of structural properties with design; design and material for low temperature application; and casting weldments.

Individual papers will treat such subjects as the spot welding of Inconel X, the submerged-arc welding of uranium, the vacuum brazing of jet-engine materials, the welded fabrication of the Carquinez Strait Bridge, the production and repair of cast weldments for nuclear service and aluminum welding cable.

Morning and afternoon sessions will be held on Tuesday and Wednesday, while only morning sessions are scheduled for Monday, Thursday and Friday.

This year, the Technical Papers Committee has faced the difficult task of accepting less than half of the manuscripts submitted for presentation at the meeting in St. Louis—an excellent indication of the quality which will encompass the April meeting. Many of the papers are the results of research and investigations conducted within institutions of higher learning, research foundations, atomic installations, and fabricating, manufacturing and aircraft plants. Others are based on practical experiences and applications.

All technical sessions, except one, will be held at the Hotel Statler, AWS Headquarters for this meeting. The nuclear optimum session will be held at the Kiel Auditorium.

The Welding Show, featuring exhibits and demonstrations of the latest equipment, filler metals and supplies used in the welding industry, will be housed in Kiel Auditorium.

The tentative technical papers program will appear in the January 1958 issue of THE WELDING JOURNAL.

AWS DIRECTORS-AT-LARGE

Term Expires	1958	1959	1960
	F. H. Dill	J. H. Blankenbuehler	J. F. Deffenbaugh
	E. D. Peters	G. E. Linnert	A. E. Pearson
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If you are interested in better welding, lower fabrication costs and increased productivity, you will gain from investment in AWS Membership. You can learn how to join by writing AMERICAN WELDING SOCIETY, 33 West 39th Street, New York 18, N.Y.

Gustav O. Hoglund

AWS NOMINATES NATIONAL OFFICERS FOR 1958–59

Nominations for national officers of the AMERICAN WELDING SOCIETY for the 1958–59 fiscal year have been announced by the AWS National Nominating Committee. The nominees who, in the opinion of this Committee, are best qualified to steer the activities during the ensuing year are as follows: Gustav O. Hoglund, president; Charles I. MacGuffie, first vice-president; R. David Thomas, Jr., second vice-president; Arthur A. Holzbaur, Donald B. Howard, Clarence E. Jackson and Jack L. York, directors-at-large, 1958–61.

In addition, the following nominees for district directors for the 1958–60 term have been selected by the duly appointed District Nominating Committees: Edward C. Miller, District #4; James N. Alcock, District #6; Frank G. Singleton, District #8; and Francis V. McGinley, District #10. (The foregoing were the only nominations received at date of publication.)

Nominated for President

Gustav O. Hoglund

G. O. Hoglund is head of the Welding Section of the Alcoa Process Development Laboratory. He is a native of Milwaukee, Wis. After attending that city's primary and preparatory schools, he studied aeronautical engineering at the University of Michigan, and was graduated in 1925 with a Bachelor of Science degree.

For the next two years Mr. Hoglund worked in the Bureau of Aeronautics, Navy Department, in Washington, D. C., designing airplane propellers. His next position was at the University of Minnesota where he served as assistant professor of aeronautics during the college term of 1927–28.

Mr. Hoglund first became affiliated with the Aluminum Company of America in 1928 and for the next two years was employed in the Central Metallurgical Division. In 1930 he was placed in charge of the development of welding processes for aluminum.

He is now in charge of the Welding Division in the Alcoa Process Development Laboratories. He is also chairman of Alcoa's Subcommittee on Joining and proudly wears Alcoa's twenty-five year pin.

Mr. Hoglund is the author of a number of technical articles which have appeared in THE WELDING JOURNAL, the *SAE Journal* and *Mechanical Engineering*. He has been active in the AMERICAN WELDING SOCIETY, serving as a member and chairman of many committees. His AWS activities include the following: 2nd vice-president, 1956–57; Board of Directors; Technical Council; Technical Papers Committee—Past-Chairman; Finance Committee; AWS-ASTM Committee on Filler Metal; Subcommittee III—Aluminum and Aluminum Alloy Filler Metal—Chairman; Brazing Committee; and Pittsburgh Section—Past-Chairman.

In addition, he has served on the Boiler Code Subcommittee on Welding of the American Society of Mechanical Engineers.

In 1939 Mr. Hoglund was the recipient of the Lincoln Gold Medal for a technical paper on "Spot Welding the Aluminum Alloys."

Nominated for First Vice-President

Charles I. MacGuffie

Charles I. MacGuffie was graduated from Penn State in 1925 with a B.S. in E.E. He completed the General Electric Co. Test Course in 1925. He was welding specialist for Atlantic District of General Electric Co. from 1928 to 1939, operating out of Philadelphia.

In 1939, he was transferred to Schenectady, N. Y., as assistant manager of sales, Welding Divisions, and in 1951 he was appointed manager of Marketing, Welding Department.

Mr. MacGuffie's AMERICAN WELDING SOCIETY activities include: chairman, Philadelphia Section; member-at-large, Board of Directors; chairman, Manufacturers Committee, Public Relations Committee and Exposition Committee; member, Welding Journal Committee, Reserve Funds Committee and Technical Papers Committee.

His other activities include: Past-chairman, Welding Section of National Electrical Manufacturers Assn.; member, American Institute of Electrical Engineers and American Ordnance Assn.

Nominated for Second Vice-President

R. David Thomas, Jr.

R. David Thomas, Jr. was born in Oakmont, Allegheny County, Pa. He was graduated in 1937 from Cornell University with a B.S. degree in Chemistry and was granted a Master's Degree from Cornell in Chemical Engineering for his thesis, "Reactions in Electric Arc Welding." Mr. Thomas is a registered professional engineer.

Always associated with the Arcos Corp. in Philadelphia, Mr. Thomas has held the following positions with the manufacturer: Director of Research and Engineering (1937–45); Vice-President and Director of Research and Engineering (1945–55); Executive Vice-President (1955–56); and President (1956).

In the Philadelphia Section of AWS Mr. Thomas served as Secretary (1952–53), Vice-Chairman (1953–54) and Chairman (1954–55). Active on technical committees he is Chairman of the High Alloys Filler Metal Subcommittee, a member of the Subcommittees for Low Alloy Electrodes and Nickel Alloy Electrodes, and a former member of the Subcommittee for Copper Alloy Electrodes. He was Secretary (1946–50) of the Joint Navy-NEMA Committee charged with the development of low hydrogen-ferritic electrodes. With the Welding Research Council Mr. Thomas was Secretary (1948–51) of the High Alloys Committee, and is currently a member of the Corrosion Subcommittee, Welding Type 347 Steels. He is a member of the AEC Advisory Committee for project on welding Type 347 steels. He was an advisor to the National Research Council Committee on Welding during World War II, and, in 1952, served as a member of an informal committee formed by National Academy of Sciences to report on opportunities of nickel conservation in alloy-welding applications. Industry Coordinator, Electrode Group for the Ordinance Advisory Committee for the Welding of Armor, he also holds membership in two specification and research groups.

Mr. Thomas has taught various courses at Temple University and Drexel Institute of Technology. He was instrumental in instituting courses in welding at Drexel in 1952.

He has delivered papers at local and national AWS meetings, as well as in Switzerland and Belgium.

Nominated for Director-at-large 1958–61

Arthur A. Holzbaur

Arthur A. Holzbaur was graduated from Rutgers University in 1930 with a B.S. degree in Chemical Engineering. Upon graduation he was employed in steel construction with McClintic-Marshall Co. and was sent by that firm to the General Electric Co. in Schenectady to study welding and welded design. Mr. Holzbaur joined Sun Shipbuilding and Dry Dock Co.'s Engineering Department, Chester, Pa., in 1936. Until 1945 he was engaged in establishing and supervising a Welding Engineering Department. He was then transferred to the yard as General Welding Foreman, and, in 1951, was appointed General Superintendent of Hull Division.

Mr. Holzbaur was chairman of the Philadelphia Section of AWS (1945–46). He is at present a member of the AWS Marine Committee, the American Bureau of Shipping Subcommittee on Welding and the Society of Naval Architects and Marine Engineers. A chapter entitled "Methods of Joining Structural Parts," authored by Mr. Holzbaur appears in the SNAME textbook, "Design and Construction of Steel Merchant Vessels."

Nominated for Director-at-large 1958–61

Donald B. Howard

Donald B. Howard is Staff Metallurgist, Research and Development Department of the American Car and Foundry Division, ACF Industries, Inc.

Following his graduation in 1939 from Colgate University, he became a metallurgist at the American Steel and Wire Division of United States Steel Corp. During the past nine years with ACF he has devoted much effort to the evaluation of new welding materials and processes and their subsequent applications in the railway equipment and Ordnance fields.

Mr. Howard is currently AWS District Director for District #2, a position that expires in May 1958. He is also affiliated with the following activities of AWS: Technical Council of the Board of Directors; Headquarters Housing Committee; Membership Committee; Section Advisory Committee; Subcommittee "A" of Educational Activities Committee; Committee of Filler Metal; and various special committees on membership classification and sustaining membership.

He is also a member of the American Society for Metals.

Nominated for Director-at-large 1958–61

Clarence E. Jackson

Clarence E. Jackson was born in Graceville, Minn. He graduated from Carleton College with honors in physics in 1927, and engaged in graduate work at George Washington University. Upon completing his studies, he joined the National Bureau of Standards.

Mr. Jackson was associated with the following branches of the government: Metallurgy Division (1930–36); U. S. Naval Gun Factory, Metallurgy and Testing Division (1936–37); and Naval Research Laboratory (1937–46). In 1946 he accepted a position as head of Welding Section, Metals Research Laboratories of Electrometallurgical Corp., and in 1956 was made Manager of their Welding Group. In 1957 Mr. Jackson was elevated to his present position as Staff Engineer for Linde Development Laboratory.

Mr. Jackson's AWS activities include: Director for District No. 3 (1953–56); past chairman of the Washington, D. C. and Niagara Frontier Sections; and, presently, Chairman of the Educational Activities Committee. He was also a representative on Mission 250 in Europe under the sponsorship of the Welding Research Council, the Ship Structures Committee and Ship Structures Committee on Organization of European Economic Cooperation in 1955. He has been active on a number of committees of the Welding Research Council, particularly those which pertain to weldability and interpretive reports. Mr. Jackson has presented numerous talks before various sections, and has authored more than 20 papers on welding and metallurgy.

Mr. Jackson was given the Distinguished Civilian Service Award in 1945 by the Secretary of the Navy. He also received the Samuel Wylie Miller Memorial Medal in 1956.

Nominated for Director-at-Large 1958–61

Jack L. York

Jack L. York was born in Shreveport, Louisiana. Besides completing his high school training, he studied mechanical engineering through the I.C.S. program. He was employed as Welding Supervisor in 1939 by Ingalls Shipbuilding Co. and later as Research Engineer. In 1941 he was appointed Welding Engineer by the J. A. Jones Construction Co., and soon thereafter was made Hull Construction Superintendent for the Brunswick Shipyard in Georgia. In 1944 he was appointed Assistant General Superintendent of Hull Construction for McCloskey Builders. After World War II, Mr. York was transferred to Philadelphia by McCloskey as Superintendent of Welding and Steel Fabrication and Erection. He joined McDonnel Aircraft Co., St. Louis, in 1947, and became Welding Engineer for the Hoffman Wolfe Construction Co. in Atlanta, Ga. and Columbus, O. In 1955, Mr. York was named Chief Welding Engineer by the J. B. Beaird Co., Shreveport, La. He is presently Chief Welding Engineer for the Delta Tank Mfg. Co. in Baton Rouge.

Mr. York played a prominent part in organizing the AWS section in Brunswick, Ga. He was also intrumental in organizing the Tri-Cities, Holston Valley and Shreveport Sections. He is a past chairman of these three sections.

Nominated for District Director 1958–60

Edward C. Miller

District 4, Southeast

Edward C. Miller was graduated from the Missouri School of Mines with a B.S. degree in Metallurgical Engineering, and obtained his M.S. degree from the University of Idaho. He then worked in nonferrous metallurgical development in Montana and Pennsylvania. Mr. Miller taught metallurgical engineering for eight years at Purdue and Wayne Universities. He served as a commander in the Navy during World War II. For the past nine years Mr. Miller has been Inspection Engineer at the Oak Ridge National Laboratory, Oak Ridge, Tenn., an organization operated by Union Carbide Nuclear Co. for the Atomic Energy Commission.

A past chairman of the Northeast Tennessee Section, Mr. Miller is the present Chairman of the AWS Committee on Piping and Tubing. He is also a member of AIME, NACE, SNT and ASTM, and is a registered professional engineer. He has published papers and given talks to various technical societies on the subjects of liquid metals, nuclear metallurgy, zirconium and code fabrication of nuclear-reactor pressure vessels.

James N. Alcock

District 6, Central

James N. Alcock was born in Sandusky, Michigan, and attended Wayne University. In 1930 he accepted a sales position with Compressed Industrial Gases, Inc. He was promoted to branch manager of this company in 1940 and continued in this capacity after CIG merged with National Cylinder Gas Co. In 1942 Mr. Alcock formed his own firm, Saginaw Welding Supply Co., which he still heads. He was instrumental in establishing Wolverine Gas Products, Inc. in 1945, a company he now serves as vice-president and treasurer. He also maintains a financial interest in Bairley & Lindley Inc., road contractors of Trenton, Mich.

Mr. Alcock was chairman of the Flint Division when it was a part of the Detroit Section. At the close of World War II the Board of Directors of the Detroit Section appointed him chairman of a special committee to organize the Saginaw Valley Section. He has served on the Board of Directors and as Membership Chairman of this section.

Mr. Alcock was one of the founders and charter members of the National Welding Supply Association. He has served as president and is currently on the Advisory Board. He is also a member of the Finance and Catalog Committees.

Frank G. Singleton

District 8, Midwest

Frank G. Singleton, owner of Singleton Welding Supply of Kansas City, has been affiliated with the AMERICAN WELDING SOCIETY for many years. He has served through all the officer posts of the AWS Kansas City Section. In addition, he served one term as Director of District No. 8 and was Chairman of the Kansas City Arrangements Committee during the AWS Welding Show in June 1955. Mr. Singleton is currently a member of the Finance, Section Advisory and Membership Committees of the national Board of Directors. He is also a Director of the Kansas City Section.

Francis V. McGinley

District 10, Western

Francis V. McGinley graduated from the University of Southern California with a B.S. degree in Business Administration. At U.S.C. he starred in football. He is currently Assistant District Manager and Sales Manager of the Los Angeles Division of the Victor Equipment Co.

During Mr. McGinley's term as chairman of the Los Angeles Section (1955–56), the section grew to the point of becoming the largest in the AMERICAN WELDING SOCIETY. He has been a member of the Section's Board for many years.

●

District Representatives on the National Nominating Committee

Eleven nominees to serve as District Representatives on the National Nominating Committee have also been selected by the National Nominating Committees. The names of their candidates for the 1958–59 term are as follows:

District No.	*Nominee*
1	Herbert Turck, Massachusetts Engineering Co., Inc., 15 Fayette St., North Quincy 71, Mass.
2	(not available at date of publication.)
3	B. C. Motl, A. O. Smith Corp., 439 Seventh Ave., Pittsburgh 19, Pa. (Res.) 5834 Horseshoe Dr., Bethel Park, Pa.
4	T. R. Berg, Jureit Associates Laboratory, Inc., 8410 Bird Rd., Miami 55, Fla. (Res.) 6315 SW 16th Court, West Hollywood, Fla.
5	R. B. McCauley, Department of Welding Engineering, Ohio State University, Columbus 10, O.
6	R. H. Hoefler, Kaighin & Hughes, Inc., Atlantic & Spencer Sts., P. O. Box 962, Toledo 1, O.
7	I. L. Baugh, Allis-Chalmers Mfg. Co., 3000 S. 6th St., Springfield, Ill.
8	L. N. Williams, Darby Corp., 1st & Walker Sts., Kansas City, Kans.
9	Roy D. Sprague, Campbell Steel Co., P.O. Box 486, San Antonio 6, Tex.
10	Harry Butler, Linde Co., 6702 Parapet, Long Beach, Calif.
11	W. R. Smith, General Electric Co., Atomic Power Equipment Dept., Richland, Wash.

●

In accordance with National By-Laws, ballots will be mailed to all Society members on or before December 26, 1957. Balloting will close on Jan. 27, 1958. Election results will be published in the May 1958 issue of THE WELDING JOURNAL. Elected nominees will officially assume office on June 1, 1958.

THINGS YOU SHOULD KNOW

(That Happened in October)

● Secretary Emeritus M. M. Kelly called at SOCIETY headquarters October 16th to visit with staff members, showing her usual keen interest in SOCIETY activities and accomplishments. Six days later she was stricken by a fatal heart attack as reported elsewhere in this issue.

● Early in October Past President Jack Chyle issued letters heralding the start of a new drive for Sustaining Members. During the 1956–57 year President Chyle personally conducted the most successful campaign in SOCIETY history for recruiting Sustaining Members, increasing the total by almost forty. In New York late in October, in connection with one of his many important technical committee activities, "Jack" spent the afternoon and evening of October 26th with your Secretary and Mrs. Plummer.

● At the October 8th meeting of the AWS New York Section, with H. S. Blumberg presenting a fine technical talk and Chairman A. L. Seiden presiding, your Secretary spoke briefly about major aims of the SOCIETY.

● During the week of October 10th, the American Society of Civil Engineers held their annual meeting at Hotel Statler. Your Secretary represented AWS at two important functions and informally discussed a future joint session to be devoted to welded construction.

● On October 15th your Secretary drove Dr. Charles Keel to Hartford, Conn., for an inspection of the Pratt and Whitney jet engine plant at E. Hartford with John Mortimer as host, and later, to the dinner meeting of the AWS Hartford Section. Dr. Keel who is Director of the Swiss Welding Society discussed welding practices in Europe at the well attended meeting, at which Chairman Clint Swift presided.

● On October 17th Dr. Keel and your Secretary traveled to Hicksville, for a dinner meeting of the AWS Long Island Section where Chairman J. Jungbluth conducted the program which included the talk by Dr. Keel with your Secretary acting as Technical Chairman.

● October 21st was the date which Queen Elizabeth II visited New York and was honored at a luncheon at the Waldorf Astoria Hotel. At the same time and in the same hotel, delegates to the Second World Metallurgical Congress sponsored by ASM were welcomed to the United States at a luncheon with I. W. Wilson, president of Alcoa, and Charles White, president of Republic Steel, delivering the principal speeches.

● Your Exposition Committee met in New York on October 22nd and decided to recommend that AWS Annual Meetings and Welding Expositions be held in the following cities during the next five years: 1958, St. Louis (April 14–18); 1959, Chicago (April 6–10); 1960, Los Angeles; 1961, New York; and 1962, Cleveland.

● H. J. Stetina, Chairman of our Welder Registration and Certification Committee, met with your Secretary, TAC Chairman Art Kugler and Technical Secretary Ed Fenton on October 28th to coordinate important proposals covering qualification, certification and registration of welders. First priority is being given to these problems in the hope that definite recommendations may soon be presented and approved, bringing at least a partial solution to questions which have been studied for many years.

● AWS Susquehanna Valley Section designated October 30th as National Officers Night and held a meeting at the Berwick Country Club. An attack of the "flu" kept President Sander from attending as planned. However, District Director Don Howard was present to hear your Secretary give a technical talk, with Chairman A. F. Belford presiding. Your Secretary enjoyed inspection trips through plants of A. C. F. Industries at Berwick and Milton, with Bill Schuster, J. M. Cameron, Don Howard and Charles Gallicano serving as guides and generous hosts.

● Chairman C. E. Jackson held a meeting of the Educational Activities Committee in Scranton, Pa., on October 16th. Limited near term objectives were set up for each of the main subcommittees. A report covering the Philadelphia Educational Symposium has been prepared and distributed to all Sections with the request that each section educational representative use it as a basis for a short talk on education. The committee has agreed to prepare a suitable chapter on welding for the Ironworks Fabrication Manual used for apprentice training.

● Editor Art Phillips reports many favorable comments on the First Section of the Fourth Edition of the WELDING HANDBOOK. Our overseas friends will be pleased to learn that in the "Sterling Area" they may use their own currency to purchase the HANDBOOK from the Cleaver-Hume Press Ltd. (31 Wright's Lane, Kensington, London W. 8., England). The New York Public Library selected the HANDBOOK for display in its Technical Book of the Month Exhibition.

● TAC Chairman Art Kugler and Technical Secretary Ed Fenton direct and coordinate an unusually large and diversified list of important SOCIETY activities. Late in September they met with representatives of National Board of Fire Underwriters and other interested groups to discuss a proposed ordinance on welding and cutting as related to fires. This is typical of the constant efforts of committee and staff members to ensure that only proper restrictions are included in such regulations. The same two men recently prepared a new statement about welding for the Encyclopedia Brittanica to replace an older one considered inaccurate and obsolete.

● AWS is constantly striving to "simplify" welding. The latest aluminum filler metal specification is an excellent example. Aluminum Association numbers are used and the previous 24 classifications have been reduced to 16. For the first time for a filler metal specification an X-ray Film Standard is used, eliminating the time-consuming and expensive job of machining and testing coupons by permitting the use of an X-ray of the test plate which is then compared with the Film Standard.

Revised specifications for Copper and Copper-Alloy Welding Rods have just been issued, including eleven classifications covering rods for oxyacetylene, carbon-arc and gas tungsten-arc welding processes.

The Joint AWS-AFS Committee on Welding Iron Castings has started the second phase of the test program to find the best procedure for welding cast iron, with 14 companies participating in the welding of 180 test samples of gray, nodular and malleable cast iron by the arc, gas and braze welding processes. Each company will use procedures found to be most promising in the first phase of the program.

Fred L. Plummer

INSTRUCTIONS FOR PROSPECTIVE AUTHORS

Authors who plan to submit papers for publication in THE WELDING JOURNAL are invited to send for a free copy of the booklet "Instructions and Suggestions for Authors." All requests should be addressed to Editor, THE WELDING JOURNAL, American Welding Society, 33 W. 39th St., New York 18, N. Y.

EAC DOINGS

Training for Skills

By W. J. Williams

Skill is no accident. Ask the person who has it. He will undoubtedly tell you that many hours of study and practice were necessary before he acquired the skill. Skill, therefore, whether it is work skill or sport skill, requires some effort by the person seeking that skill. Training and experience are ingredients in the recipe for all skills. Education, however, combined with training can speed the process of obtaining work skills.

There are three main ways of obtaining an education: (1) from customs, or habits, of a particular group or culture; (2) from a program whose primary aim is entertainment; and (3) from some program whose primary intent is to promote learning.

Walking on sidewalks, eating certain foods and avoiding others, living in houses, and so on, are examples of education obtained through customs or habits. This type of education takes place almost automatically.

Many media whose prime functions are entertainment are sources of education. Television, radio, theaters, conversations, literature all add to our knowledge. A child watching his Dad use a soldering iron learns that touching hot metal is painful when he sees his father accidentally get a severe burn. The child's vocabulary, too, may be augmented. He did not have to experience the actual burn to learn that hot metal should be avoided.

A child does not have to ride a horse and actually shoot a gun to know what the West was once like. The comic book, the picture and the television program will give him this information.

Schools, institutes, colleges and universities are included in the group whose primary intent is to teach and where an institution is set up to promote learning. Through them, education is actually the process of a deliberate attempt to fashion experiences which will direct and control learning. The education program on which the Educational Activities Committee is now working is concerned with fashioning experiences by the direction and control of learning. The program will be of immense benefit for the training of persons now in the field of welding, as well as for persons who would like to get into this field.

The job ahead of the Committee is not easy. Each of the eight major groups, the thirty-seven processes included in these groups, and the different job levels as they apply to each group and process have to be considered. Otherwise, too much emphasis may be placed on one aspect and not enough on another. The needs of industry and the needs of the individual must be considered carefully.

Knowledge comes through study and understanding; ability through practice. Every experience that a learner goes through is an element in his education, but unless the experience is related to his personal goal it will be of little immediate benefit to him. All progress is change, but not all change is progress.

Principles of Learning

Any educational program must consider the three principles of human learning: (1) motivation, (2) self-activity, (3) perception.

Without motivation there is no self-activity. Motivation is the most critical aspect of any educational program. The program should be set up so that it will not only excite the interests of those for whom the program is intended, but also hold these interests.

Self-activity, or the desire to continue, is very important. It is possible to excite interests, but a rapid cooling off can take place before any action is taken.

Perception must be directed or false conclusions may result. Consider the following example of the different perceptions when the same object is viewed. Three men standing on a river bank look at a new bridge crossing the river. One considers the amount of steel used in the bridge; the second, the graceful sweep of the bridge. The third wonders whether his business will suffer because of the bridge.

All three perceived the same bridge, but they perceived it in terms of past experiences. The first was a welding engineer, the second an artist, and the third an owner of a refreshment stand on a highway being by-passed because of the bridge.

The Educational Activities Committee is aware of the needs of an educational program and the many levels on which it must be conducted.

When the results of the various programs have been evaluated, the experience gained will be exceedingly valuable in the revision of old, and the preparation of new, educational programs.

William J. Williams is Director of the School of Shop Practice, International Correspondence Schools, Scranton, Pa.

EAC MEETS AT INTERNATIONAL CORRESPONDENCE SCHOOL

Pictured at a recent meeting of the AWS Educational Activities Committee in Scranton, Pa., are (*left to right*): William J. Williams, W. G. Leaman, Arthur L. Phillips (secretary), Clarence E. Jackson (chairman), T. Embury Jones, George G. Luther and H. A. Sosnin.

Section News and Events

as reported to Catherine O'Leary

MAGNETIC-FLUX PROCESS

Fort Wayne, Ind.—The meeting of the *Anthony Wayne* Section on September 19th was held at the plant of the Dana Corp. in Fort Wayne. Featured speaker, H. M. Gregoire AWS, the Linde Co., spoke on the magnetic-flux gas-shielded arc-welding process. The speaker used motion pictures to illustrate his topic. A live demonstration of the process was then performed by representatives from the Sutton-Garten Co., Linde distributors in the area.

The meeting was preceded by a motion picture which discussed the "Powr-Lok" differential manufactured by the Dana Corp. for automobiles and trucks.

WELDING PROCEDURES

Phoenix, Ariz.—The second regular meeting of the season of the *Arizona* Section was held in the Sky Room of the Sahara Hotel on Wednesday, October 16th, at 7:30 P.M. There were 33 present, eight being students from Valley high schools and colleges.

Paul Kano and Stanley Pine of the Arizona State College Farm Shop; Robert Rowland and Carlos Ferrero of the advance day class, Phoenix Union High School; and Dale Hunler and Richard Hansen, Phoenix Union Chapter F.F.A., were the guest students for the night. Other guests were Harold K. Miller from Camelback High School, R. K. Barnard from Dye Oxygen Co., and Dom Lesei from Rafter Engineering Co.

Technical speaker, Robert H. Aborn AWS, U. S. Steel Corp. Research Center, Monroeville, Pa., gave an interesting talk accompanied by slides, entitled "Welding Procedures and Arc Characteristics of Electrodes." Dr. Aborn also showed a movie on different arc characteristics of electrodes.

JOINING METALS

Birmingham, Ala.—Seventy members and guests of the *Birmingham* Section met on October 8th for a dinner meeting at Gulas Restaurant.

Speaker at the meeting was Lawrence L. Kelly, AWS, Southern Manager, Engineering Service, Linde Co. Mr. Kelly's presentation on "Modern Methods of Joining Metals" included a motion picture and slides discussion of four welding methods which have gained prominence in recent years. The processes discussed were: (1) submerged-arc welding, (2) inert-gas-shielded tungsten-arc welding, (3) inert-gas-shielded metal-arc welding and (4) gas-shielded magnetic-flux arc welding.

WELDING DESIGN

Bridgeport, Conn.—The *Bridgeport* Section met for a dinner meeting on October 17th at the Fairway Restaurant.

Thomas L. Dempsey AWS, general manager of Industry and Welding, gave a talk which was of extreme interest to the twenty members present. He revealed figures and statistics on the arc welding industry in this country which were very interesting. Mr. Dempsey went into detail with the aid of slides on "Weldesign—its possibilities and uses." The advantages of steel fabrication over castings were well presented. A question-and-answer period ensued after Mr. Dempsey's excellent presentation.

CARBON-DIOXIDE WELDING

Chicago, Ill.—One hundred and forty members and guests of the *Chicago* Section were present on September 20th in the Auditorium of the Peoples Gas Light & Coke Co., to hear Albert J. Dearing AWS, of the A. O. Smith Corp., Milwaukee, Wis., cover the subject of CO_2 Welding. His talk was accompanied by slides which showed the various CO_2 weld setups and the operation data concerning this process. The talk was well received by the group, as evidenced by the number of questions asked the speaker. The question period lasted 45 minutes.

The motion picture shown before the meeting was a story of the Grand Canyon. The picture told about the formation of the earth and the start of the Grand Canyon.

Seventy-six members and guests were present at dinner which was held at Milner's Restaurant.

ANTHONY WAYNE SECTION VIEWS MAGNETIC-FLUX PROCESS

Members of the Anthony Wayne Section learn about the techniques used in the magnetic-flux gas-shielded arc-welding process at the September 19th meeting

Close-up of onlookers watching live demonstration at the Dana Corp.'s plant in Fort Wayne, Ind.

SECTION MEETING CALENDAR

JANUARY 3

NORTH CENTRAL OHIO Section. Marion, Ohio. "New Application on Resistance Welding," F. A. Bodenheim.

PHILADELPHIA Section. Engineers Club, Philadelphia, Pa. 7:45 P.M. Panel Discussion: Weldability of Heat Resisting Alloys.

JANUARY 6

LEHIGH VALLEY Section. Dinner 6:30 P.M. Meeting 8:00 P.M. Walp's Restaurant, Allentown, Pa. "The Battle of the Cities."

MILWAUKEE Section. 1958 Educational Course. Marquette University.

JANUARY 7

NEW YORK Section. Victor's Restaurant, 1 E. 35 St., N.Y.C. Get-Together 5:30 P.M. Dinner 6:00 P.M. Program 7:00 P.M. "Resistance Welding on Aluminum," J. W. Kehoe, Westinghouse Electric Corp.

JANUARY 8

CLEVELAND Section. Manger Hotel, Cleveland, Ohio. Social Hour 6:00 P.M. Dinner 6:30 P.M. Meeting 8:00 P.M. "Executive Night."

STARK CENTRAL Section. American Legion, Canton, Ohio. Speaker from Magnaflux Co.

JANUARY 9

SAGINAW VALLEY Section. Hi-Life Inn, Saginaw, Mich. "Ultrasonic Metal Joining," Aeroprojects, Inc.

JANUARY 10

COLUMBUS Section. Riverside Rathskellar, Columbus, Ohio. Dinner 6:30 P.M. Meeting 8:00 P.M. "Aircomatic Cutting of Aluminum," H. D. Mann, Air Reduction Co.

DETROIT Section. Engineering Society of Detroit. 8:00 P.M. "Resistance Welding of Heavy Structures," W. J. Farrell, Sciaky Bros., Inc.

JANUARY 13

MILWAUKEE Section. 1958 Educational Course. Marquette University.

NORTHWEST Section. Minneapolis, Minn. 4:00 P.M. Shop trip—Electric Machinery & Manufacturing. 6:00 P.M. Meeting. Elks Club. "Techniques and Equipment for Welded Production," John Mikulak, Worthington Corp.

JANUARY 14

WESTERN MASS. Section. Blake's Restaurant, Springfield, Mass. Dinner 6.30 P.M. Meeting 7:30 P.M. "Welding and Brazing Problems in the Atomic Energy Field," Herbert S. Kalish, Sylvania-Corning Nuclear Corp.

JANUARY 15

PEORIA Section. Mecca Supper Club, Farmington Road, Peoria, Ill. 6:30 P.M. Dinner speech 7:45 P.M. Ceramic Jewelry Demonstrations, James Polanes, Linde Co.

PITTSBURGH Section. 8:00 P.M. Auditorium of Mellon Institute of Industrial Research (Oakland) Pittsburgh, Pa. "Health and Safety in Welding," S. W. Speicher, Westinghouse Electric Corp. and L. G. Mathews, Linde Co.

PROVIDENCE Section. Dinner meeting 6:15 P.M. Johnson's Hummocks, Providence, R. I. "Control and Correction of Welding Distortions," LaMotte Grover, Air Reduction.

SOUTH FLORIDA Section. 8:00 P.M. Firemen's Benevolent Hall, Miami, Fla. "Plastic Fabrications," F. B. Miller.

JANUARY 16

BRIDGEPORT Section. "Welding of Stainless Steel," Benjamin F. Doty, Crucible Steel Co. of America.

IOWA Section. Des Moines, Iowa. "Semi-Automatic Welding," H. E. Baldwin, Westinghouse-LeTourneau.

KANSAS CITY Section. "Structural Welding," LaMotte Grover, Air Reduction.

MADISON Section. Eagles Club, Madison, Wis. "Safety in Welding Practices."

JANUARY 17

MARYLAND Section. Engineers Club, Baltimore, Md. "Resistance Welding Machine Development and Applications," F. R. Woodward, Taylor Winfield Corp.

MILWAUKEE Section. Ambassador Hotel. 6:30 P.M. "Practical Aspects of Various Welding Processes," John Mikulak, Worthington Corp.

JANUARY 20

MILWAUKEE Section. 1958 Educational Course. Marquette University.

PHILADELPHIA Section. Engineers Club. 8:00 P.M. Past Chairmen's Night. "Weldability of Carbon and Low Alloy Steels," R. D. Stout, Lehigh University.

JANUARY 21

HARTFORD Section. Villa Maria Hotel, Glastonbury, Conn. "Nondestructive Testing," Alexander Gobus, Philips Electronics, Inc.

NORTHWESTERN PENNA. Section. Erie, Pa. "Quality vs. Cost of Welding."

TOLEDO Section. Maumee River Yacht Club. Dinner 6:30 P.M. Meeting 8:00 P.M. "Hard Facing."

JANUARY 23

NIAGARA FRONTIER Section. Continental Inn, Kenmore, N. Y. Dinner 6:45 P.M. Meeting 8:00 P.M. "Welding High Strength Steels and Alloys," by Leon C. Bibber.

JANUARY 24

INDIANA Section. Plant Tour and Dinner. Fisher Body Div. GMC, Marion, Ind.

JANUARY 27

MILWAUKEE Section. 1958 Educational Course. Marquette University.

Editor's Note. Notices for March 1958 meetings must reach Journal office prior to January 1, so that they may be published in February Calendar. Give full information concerning time, place, topic and speaker for each meeting.

STAINLESS-STEEL WELDING

Chicago, Ill.—The regular monthly meeting of the *Chicago* Section was held on October 18th. The meeting was preceded by a dinner "get-together" and a delightful movie film in color which was taken at the 1957 golf party at Nordic Hills Country Club.

The film highlighted several scenes of "dubbing," "good fellowship" and more "dubbing" on the part of the members.

The technical subject of the evening was entitled "Problem Solving in Stainless-Steel Welding" and was presented by R. David Thomas, Jr. AWS, of the Arcos Corp.

He discussed some of the various approaches and methods which can be used in solving problems in stainless-steel welding. Some of the outstanding examples included the exacting welding specifications which were required on the welding of stainless-steel parts on the Nautilus atomic-reactor type submarine.

Mr. Thomas' talk was accompanied by a colored sound movie which described the operating characteristics of the EB backing insert.

Eighty-five members and guests were in attendance at dinner at Milner's Restaurant, while 198 were present at the meeting which took place in the Auditorium of Peoples Gas Light & Coke Co.

STUD WELDING

Cincinnati, Ohio—R. C. Singleton, AWS vice-president of engineering, Nelson Stud Welding Division of Gregory Industries, Inc., Lorain, Ohio, gave an excellent talk on the "Latest Developments in Stud Welding" at the October 22nd meeting of the *Cincinnati* Section held at the Engineering Society of Cincinnati Headquarters Building.

Mr. Singleton outlined the evolution of stud welding from the "freezing" of metal-arc electrodes to the efficient present-day method of attaching studs to plates. He discussed a number of significant applications in construction, automotive, railroad, heavy equipment and other production industries. A unique and interesting application of stud welding on the world's largest wind tunnel which resulted in an estimated saving of $100,000 was described. His presentation, supplemented with slides, also described the characteristics of desirable power sources for stud welding. He emphasized the need for close control over operating variables and trained operators to assure the highest quality in stud welding.

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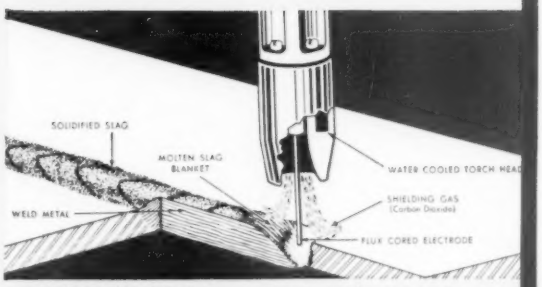
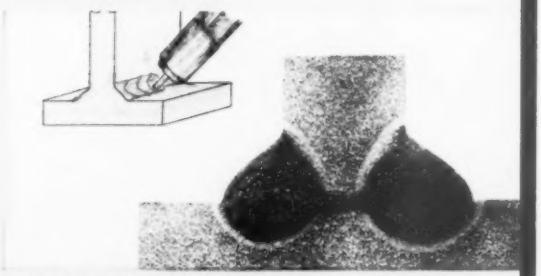
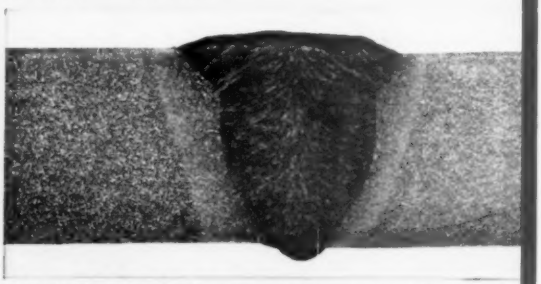
The DUAL SHIELD process is accomplished with the NCG Sureweld welding equipment. The basic Sureweld Type SA-1 outfit is for "Automanual" welding. It consists of electronic welding control, electrode drive, welding gun, and the gas and water cable assemblies. Conversion kits enable you to easily convert this to fully automatic welding. The DUAL SHIELD process makes fully automatic production welding most feasible. It is only necessary to traverse the gun or the work mechanically.



DOUBLE PROTECTION: Flux in the electrode core and a shield of CO_2 work hand-in-hand to produce sound, uniform and clean welds.



UNIFORM WELDS: Once settings are made, the DUAL SHIELD process makes smooth, uniform welds even on scaly, oily or rusty steel.



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PANEL DISCUSSION

Cleveland, Ohio—The October meeting of the *Cleveland* Section was held in the form of a panel discussion on the subject: Which Is Better—AC or DC. Speaker and panel moderator was Jerry Hinkel AWS, application engineer, Lincoln Electric Co. The dinner meeting was held in the Mather Room of the Hotel Manger with 109 at the dinner and 130 present at the meeting.

The panel consisted of O. H. Kuhlke AWS, welding engineer for the General American Transportation Co.; T. L. Dempsey AWS, general manager of Industry & Welding; Loren Miller AWS, welding engineer for the Austin Co., and E. Vere AWS, welding engineer for Lewis Welding Co.

Each panel member briefly explained, in a non-technical fashion, the reasons for using either a-c or d-c welding in their company's operations.

BRAZING

Columbus, Ohio—The first meeting of the new season of the *Columbus* Section was held at the Riverside Rathskellar on September 13th. Forty-five members and guests were present for dinner which was preceded by refreshments and a fellowship hour sponsored by one of the local welding supply houses.

Technical speaker was S. J. "Sam" Whalen AWS, of the Aerobraze Corp., Wickliffe, Ohio, who presented a talk on "High-Temperature Brazing Applications." Various nickel-base brazing alloys and their uses were covered. Among topics discussed were proper brazing procedures, methods of applying brazing alloys, properties of the resulting joints, and the proper joint design that should be used. Mr. Whalen included several specific examples pointing up the necessity of employing proper safety practices when using hydrogen atmospheres for production brazing.

SPEAK ON DESIGN CONSIDERATIONS

Jack Lemon, F. A. Bodenheim and George Motzenbecker shown at the special technical meeting held by the Detroit Section on September 19th. The topic dealt with machine and products design considerations for multi-spot welding machines

BRITTLE FRACTURE

Dayton, Ohio—The October 8th meeting of the *Dayton* Section was held at the W. H. Kiefaber Co. sales office. The meeting was opened with a color film entitled "Men of Gloucester" and followed by a second color movie, "Land of Fair Dinkum."

The films were followed by a talk on "Metallurgical Factors Influencing the Brittle Behavior of Steel Plate" by R. H. Frazier, assistant chief of

AT THE OCTOBER 11th MEETING OF DETROIT SECTION

A section of the large group in attendance at the dinner

Some of the 188 members and guests who were present at the meeting

A discussion on stock investment fundamentals was given by Wilfred G. Gill

J. B. Komenderce spoke on static controls to automated machines and welders

Paul G. Hanna assisted Mr. Komenderce in the presentation of his paper

←For more details, circle No. 7 on Reader Information Card

the Division of Ferrous Metallurgical Research at Battelle Memorial Institute.

The talk, accompanied by slides, covered the results of tests made on steel plate under low-temperature conditions and the metallurgical factors which influence brittleness under such conditions.

AUTOMATION

Detroit, Mich.—The *Detroit* Section held its regular monthly meeting on October 11th in the Rackham Building—ESD Section. The dinner and technical meeting were exceptionally well attended; there were 115 for dinner in the ESD Auditorium and about 200 at the meeting.

A very fine paper was presented by J. B. Komendera AWS, manager of Dept. of Engineering Coordination, Valvair Corp., Detroit office, and ably assisted by Paul G. Hanna, supervisory engineer, Special Apparatus Group, Westinghouse Electric Corp., Pittsburgh, Pa. A new and very interesting subject was presented on the "Application of Static Controls to Automated Machines and Welders." This is a Cypak magnetic control circuit and it is believed there will be a good many uses for this type of control in the automotive industry and other industries using automation. Representatives from National Electric Welding Machine Co., United Welders Inc. and General Electric formed a discussion panel to further develop the subject.

RESISTANCE WELDING

Detroit, Mich.—The special technical meeting of the *Detroit* Section was held on October 24th in the Rackham Building—ESD Section. This meeting was also very well attended. The speaker was John F. Cantalin AWS, of the Fisher Body Div., Production Engineering Activity, who spoke on "Resistance Welding." He did a fine job. It was agreed by all those present that anyone interested in automotive welding who fails to attend these meetings is missing some real information.

PLANT TOUR

Clintonville, Wis.—Seventy-five members of the *Fox Valley* Section were guests of the Four Wheel Drive Auto Co. in Clintonville, on October 18th.

Executives of the Four Wheel Drive Auto Co. guided groups through their entire plant. Members were treated to an inside view of processes involved in the manufacture of trucks, fire-fighting equipment and the famous Terra-Cruiser. This unusual vehicle is now used exclusively by the armed forces for negotiating the most difficult terrain conditions. Mounted on huge balloon tires, it is capable of wading through swamps or soft desert sands.

After the plant tour, dinner was served at the River Grille followed by movies depicting the development, manufacture and performance of the Terra-Cruiser, and also fire-fighting equipment.

The members of the Section hailed this plant tour as one of their most educational meetings to date.

VISITOR FROM SWITZERLAND

Dr. Charles G. Keel, Director of the Swiss Welding Society, addressed the Hartford Section on October 15th. His subject was "High Quality Welding Operations in Europe"

WELDING IN EUROPE

Glastonbury, Conn.—The October meeting of the *Hartford* Section was held Tuesday evening, October 15th, at the Villa Maria Hotel in Glastonbury. After cocktails and dinner, the members were privileged to hear a talk on "High-Quality Welding Operations in Europe," presented by Dr. Charles G. Keel, who since 1946 has been director of the Swiss Welding Society and editor of the "Swiss Welding Journal."

The Section was also honored to have as its guest for the evening, National Secretary Fred Plummer, who accompanied Dr. Keel on his trip to Hartford from New York.

Dr. Keel spoke on problems encountered in the building of highway and railroad bridges, penstocks, sluice gates, and the welding of massive pieces of alloy steel to plain steel in the manufacture of heavy machinery.

In the introductory remarks Dr. Keel stated that high-quality welding is only possible where full reliance can be placed on sound constructional design, the proper selection of materials, correct stress calculation, efficient shop appliances, proper shop preparation, meticulously accurate execution of shop work, periodic examination of the welding operators, appropriate preheating and thermal post-treatment and suitable materials testing.

The speaker first discussed the question of stress calculation in regard to welds. By reference to comparative diagrammatic representations it is shown that in various European countries there is in some cases a marked difference in the maximum safety seam coefficients used for butt and fillet welds.

The first example taken was that of the welded sluice-gates installed in the Rhine power station at Birsfelden (Switzerland).

In view of the substantial wall thickness of 2^1_2 in. and the great static pressure of approximately 2000 tons the choice of material called for the greatest care. A detailed description was given of requirements in regard to liability to brittle fracture and weldability.

The next example taken was that of two all-welded railway bridges in Switzerland. In these cases, stress calculation was based on dynamic loads. Here again the steels used were tested according to a special testing program.

The third example concerned all-welded penstocks for hydro-electric stations which have been put into service in Switzerland and Austria in recent years and work with a pressure head of up to 5900 ft.

The speaker described novel testing methods for the purpose of ascertaining the weldability of steels by means of internal explosion tests and gave details of the welding technology applied to such penstocks, which are designed to withstand maximum admissible stresses of 30,000 psi and upwards.

As a fourth example the author described two highway bridges recently built across the Rhine at Speyer (Germany) and Basel (Switzerland) which are almost entirely welded in construction. The weight of steel of 640 and 930 lb/sq ft, respectively, represents a remarkably economical design.

Here again great care was devoted to the selection of steel.

As his fifth example Dr. Keel took the welding of massive pieces of alloyed and plain steels in machine building. Particulars were given of the problems arising in the construction of gas and steam turbines in re-

gard to the welding of alloyed steels of great thickness and weight.

The next example concerned welded spherical pressure-gas containers recently constructed in Germany. These were designed to have seam coefficients of V = 0.9 and were treated with the low-temperature stress-relieving method. An interesting example shows that successful attempts are being made in Europe to explore new avenues in crane building by using thin sheet metal instead of lattice constructions.

In conclusion pictures from England and France showed that spot welding has already been successfully introduced in steel construction.

VISIT BY NATIONAL OFFICERS

Beaumont, Texas—Two outstanding speakers were featured at the September 26th meeting of the *Sabine Division* of the Houston Section. They were National President Clarence P. Sander and National Secretary Fred L. Plummer.

The Messrs. Sander and Plummer arrived at Beaumont at 9:00 A.M. and were conducted by Glen L. Martin, plant manager of the American Bridge Division of the U. S. Steel Corp., and Mr. Pennington, general manager of Levingston Shipbuilding Corp., through the fabricating plants of each firm. At the American Bridge Division, they toured the pipe mill, fabricating shop, heavy plate shop, the construction ways, and visited the site of American Bridge's new $6,000,000 expansion. At the Levingston plant they toured the main land yard and the island where they witnessed the launching of a barge as well as viewed the building of other offshore drilling equipment.

Mr. Sander's talk covered very thoroughly the activities of the National Society giving some very interesting statistics on membership, society officers, society expenses and financial status. Mr. Plummer's talk covered the very interesting field of design and construction of large storage tanks and pressure vessels. He elaborated on the problems of design, fabrication, welding, including joint preparation, types and sizes of electrodes used in welding, testing of tanks and X-ray inspection. His talk was illustrated with slides which covered every phase of tank building as well as some interesting shots of his tour of Japan.

SPEAKS IN HOUSTON

Harry F. Reid, Jr. who spoke on the welding of stainless steels at the October 23rd meeting of the Houston Section

SANDER AND PLUMMER ADDRESS SABINE DIVISION

President C. P. Sander and Secretary Fred L. Plummer were the guest speakers at the September 26th meeting of the Sabine Division of the Houston Section. Pictured above, front row, left to right, are the Section Chairman Paul Reitz, Mr. Plummer, Mr. Sander, and Section Vice-Chairman Bill Brandt. In back row are Division Director Sid Buell, Geo. P. Trotter, Joe H. Hoffman and Don Reichle, and Section-Treasurer Bob Snyder

President Sander presenting a brief talk on the activities of the National Society and its staff. Secretary Plummer spoke on design for welded plate fabrication

WELDING STAINLESS STEELS

Houston, Texas—One hundred and sixteen members and guests of the *Houston* Section met on October 23rd at the Ben Milam Hotel in Houston to hear an excellent talk on "Welding of Stainless Steels" as given by Harry F. Reid, Jr. [illegible], manager, Technical Service Div. of the McKay Co., York, Pa. Mr. Reid presented a generalized discussion of stainless steels and the problems encountered in welding various types. Recent developments and trends were empha-

sized. Stainless-steel electrodes and electrode manufacturing processes were described.

Before the meeting, an excellent movie on "The American Cowboy" was shown through the courtesy of the Humble Oil & Refining Co.

WELDING STAINLESS STEELS

Beaumont, Texas—Fifty-two members and guests of the *Sabine Division* of the Houston Section met on October 24th at the Flying Chef Cafe, Jefferson County Airport, to hear an excellent talk on stainless steel as given by H. F. Reid AWS, manager, Technical Service Div., the McKay Co., York, Pa. Mr. Reid's talk covered the composition of stainless steels, comparison of stainless steel with carbon steel and the effect of chrome content on strength. He discussed the three major groups of stainless steels; gave the factors influencing welding of martensitic stainless steel and ferritic stainless steel. He covered the composition range of austenitic electrodes as well as typical coating of stainless-steel electrodes. Mr. Reid closed his talk with a poem called "If."

A LOOK AT THE IIW

Indianapolis, Ind.—The first meeting of the new season for the *Indiana* Section was held at the Indianapolis Athletic Club on September 27th. A social hour was held at 5:30 P.M. and a delicious dinner was served to 59 members and guests at 6:30.

The featured speaker of the evening was T. Embury Jones AWS, president of Precision Welder and Flexopress Corp., Cincinnati, Ohio.

Mr. Jones, who was the United States official delegate to the last two International Institute of Welding meetings, gave a very interesting and informative talk entitled "A Look at the International Institute of Welding."

PLANT TOUR

Columbus, Ind.—On Friday, October 25th, eighty-four members and guests of the *Indiana* Section were treated to a fine dinner and plant tour through the Gladstone Muffler Plant of Arvin Industries at Columbus. Frank Mattox, Gladstone plant superintendent, welcomed the guests and R. D. Battleson, industrial engineer, gave a thorough explanation of the construction, layout and purpose of the plant as well as other interesting facts about Arvin Industries. There followed a highly informative tour conducted by members of the Arvin management.

LEHIGH VALLEY SECTION HEARS HUMBERSTONE

Past President Joseph H. Humberstone spoke on "The Development of Welding for Engineering Fabrication" at the October 7th meeting of the Lehigh Valley Section. Left to right, above are: Section Chairman R. A. Bartholomew, Mr. Humberstone and Vice-Chairman C. L. Jensen

WELDING METALLURGY

Des Moines, Iowa—The regular monthly meeting of the *Iowa* Section was held on October 10th at the Hotel Kirkwood in Des Moines. Dinner preceded the meeting.

Speaker was Julius Heuschkel AWS, consulting welding engineer for the Westinghouse Research Laboratories.

Mr. Heuschkel's subject was "Basic Metallurgy of Welded Steel Fabrication," and was illustrated by slides covering ferrous alloys only. His subject on basic metallurgy was very interesting to nontechnical people. He stressed the importance of knowing the properties of metals at elevated temperature and the effect of cooling rate on fracture. He mentioned that porosity in welds is generally caused by gas in metals, nitrogen and cooling rate.

CONTOUR BEVELING

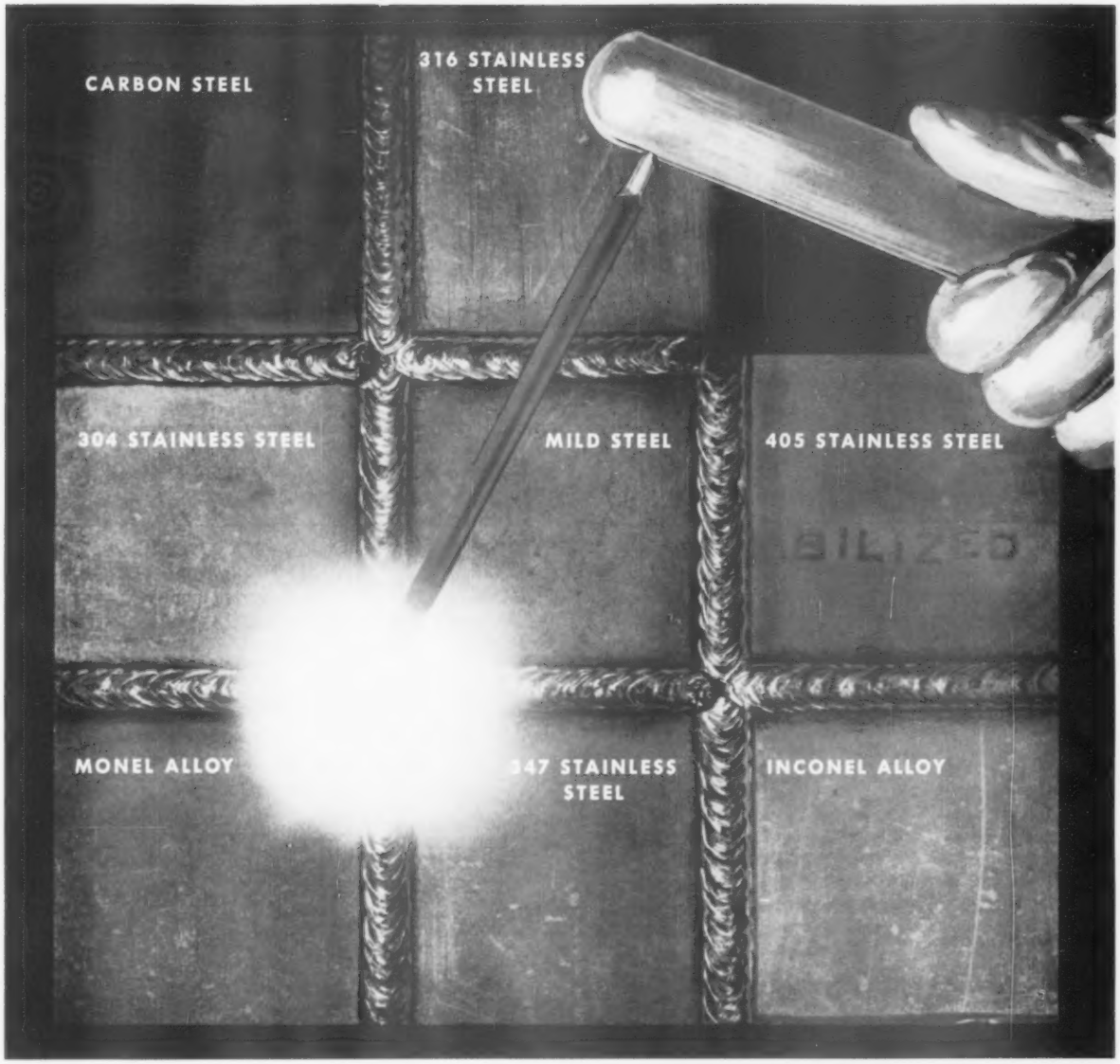
Kansas City, Mo.—The October meeting of the *Kansas City* Section was held on October 10th at the Golden Ox Restaurant and attracted a fine crowd of 54 members and guests.

After an excellent steak dinner, the group was shown the first TWA travelogue movie entitled "Flight to California" and seemed to enjoy it very much.

The speaker of the evening was R. F. Helmkamp AWS, Air Reduction Sales Co., New York City, and the title of his talk was "Contour Beveling with the Electronic Tracer." He showed slides illustrating the use of the manual type of shape cutting and the electronic method. One set of pictures showed the cutting of 6-ft thick pieces of steel resulting from slag dumping at a steel mill. He also

MAKING PLANS FOR LOS ANGELES SECTION

New officers of the Los Angeles Section huddle over coffee at the Executive Committee meeting on September 12th (*left to right*) are: Secretary R. C. Hayes, Vice-Chairman John B. Ross and Chairman D. P. O'Connor



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LAGE SPEAKS ON PRESSURE WELDING IN LOS ANGELES

Arnold Lage was guest speaker at joint meeting of Los Angeles Section and Aircraft and Rocketry Panel on September 19th

Program Chairman Howard Eubanks congratulates Mr. Lage on excellent presentation on the application of pressure welding in the aircraft industry

National Membership Chairman Charles B. Smith addressing the meeting; (*left to right*) Al Thompson, Mr. Smith and Dave O'Connor

showed a short movie on the operation of the electronic multi-torch for shape cutting.

ENGINEERING FABRICATION

Allentown, Pa.—The *Lehigh Valley* Section met for dinner and meeting on October 7th at Walp's Restaurant in Allentown. The coffee speaker Prof. Wm. J. Eney, head of Civil Eng. Dept., Fritz Eng. Lab., Lehigh University, pointed out in his talk that research was needed by industry in order to stay in business. Instances were cited of companies going out of business because of their lack of a research program. There is a large research program at Lehigh but the lack of interest in research on the part of American youth will result in a future shortage of teachers, so says Prof. Eney.

Technical speaker was Joseph Humberstone AWS, president of Air Reduction Sales Co. Mr. Humberstone chose as the title of his talk: "The Development of Welding for Engineering Fabrication." Mr. Humberstone showed slides in connection with his talk on the growth of welding and its application with new metals. The expanding field of automatic welding of very thin stainless steel and small-diameter steel tubing at 800 fpm was noted. He noted that atomic energy would be impossible without welding and the construction of nuclear reactors was a major accomplishment for the welding industry. Application of welding in modern aircraft construction was also another accomplishment for welding and he noted the close tolerances required in aircraft jet engines and the reliability of welding in supersonic flight which is no longer questioned.

The great number of applications of welding in the auto industry reduced the cost of automobiles and as an example the speaker noted the volume produced of welded sheet steel parts.

Welding in the shipbuilding field was responsible for a 5 to 10% saving in shipbuilding fabrication time and reduced maintenance. The adaptability of welding to various metals was cited by noting the use of welded aluminum in warships.

The technology of welding must be given to industry from research. Sufficient time is not given to welding by our schools of engineering and education of the individual in welding must continue in industry.

The AWS meetings help to bring together the three groups interested in welding.

WELDING FUNDAMENTAL PRINCIPLES

Hicksville, L. I.—Fifty-five members of the *Long Island* Section attended the September meeting held on September 17th at Henningsen's Restaurant in Hicksville. A social period and dinner preceded the meeting which was addressed by R. E. Taylor AWS, the director of the National Technical Training Services of Canada. Mr. Taylor organized this group last November and it has since been licensed by the State of New York.

His talk, titled "Welding Fundamental Principles and Practices," pointed out the need for welding supervisors, foremen, designers and operators in the welding field to obtain technical training in order to achieve the ultimate objective of higher quality welding at lower cost. In his 31 years since graduation from college, Mr. Taylor has been very much concerned with this aspect of welding problems.

EXECUTIVE COMMITTEE

Los Angeles, Calif.—The *Los Angeles* Section held its first Executive Committee meeting for the fiscal year, with the new officers presiding, on September 12th, at the Los Angeles Athletic Club.

Those present were David P. O'Connor, Section chairman; John B. Ross, Section vice-chairman and program chairman, and Richard C. Hayes, secretary. Also on hand were these Committee chairmen: Mario L. Ochieano, Publicity; Alan Flanigan, Education; George Murphy, Membership; John Wiley, Entertainment; Charles W. Concannon, Ways and Means; and Frank R. Drahos, Technical.

Guests present were: Leo West, chairman, Aircraft & Rocketry Panel and Howard Eubank, Panel vice-chairman.

JOINT MEETING

Huntington Park, Calif.—The *Los Angeles* Section and the *Aircraft and Rocketry Panel* held a joint technical meeting to start the new 1957–58 fiscal year.

The meeting was held at the Elks Lodge in Huntington Park on September 19th. Dave P. O'Connor, Dept. of Water and Power and chairman of the Section, conducted the meeting. Howard Eubank, Convair-Pomona, program chairman of the Aircraft and Rocketry Panel, introduced the guest speaker, who was Arnold Lage

AWS, supervisor of Weld Group, Menasco Manufacturing Co., Burbank, Calif.

Mr. Lage spoke on "Applications of Pressure Welding to the Aircraft Industry." The pressure welding of low-alloy steels heat treated after welding of 260–280,000 psi, Inconel X and titanium alloys were discussed. The paper was well supported by slides. An enthusiastic question-and-answer period followed the presentation.

Charles B. Smith, National Membership chairman, also addressed the meeting and stressed the importance of their continued growth in membership. He challenged the Los Angeles Section to equal or better 1000 members by the year's end.

WELDING IN EUROPE

Huntington Park, Calif.—The monthly meeting of the *Aircraft and Rocketry Panel* of the Los Angeles Section was held at the Elks Lodge in Huntington Park on October 3rd. The dinner was attended by 78 members and guests. Total attendance was 103.

The chairman introduced the president of the SOCIETY, C. P. Sander, past chairman of the Los Angeles Section, and other distinguished guests.

Technical speaker was Dr. Charles G. Keel of Basle, Switzerland, who spoke on the subject of "High Quality Welding Operations in Europe" and showed color slides of scenic areas in his native country.

In his talk, Dr. Keel discussed basic weld quality concepts; European codes governing the design of welded structures; the design of welded bridges, penstocks and pressure vessels; and manufacturing and quality control techniques used in Europe in the fabrication of welded structures. The talk was accompanied by lantern slides of photographs and drawings illustrating the various items covered.

After closing the technical lecture, Dr. Keel presented a short travelogue on Switzerland.

WELDING STAINLESS STEEL

Beloit, Wis.—Seventy-five members and guests were present at the October meeting of the *Madison* Section held on October 10th at the Fairbanks Morse Clubhouse in Beloit.

The technical program on the "Welding of Stainless Steels" was covered by D. W. McDowell, Jr. AWS, Stainless Steel & Heat Resistant Alloy Section, Development & Research Division, the International Nickel Co., Inc., New York. Mr. McDowell gave an excellent talk on the subject. His phraseology and technical terms were understood by all. He kept his talk short and to the point and was well liked by all.

ROCKETRY PANEL ADDRESSED BY KEEL

Charles G. Keel, director of Swiss Welding Institute, spoke at the October 3rd meeting of Aircraft and Rocketry Panel of Los Angeles Section. *Left to Right* are Panel Chairman Leo West, Dr. Keel and Los Angeles Section Vice-Chairman John B. Ross

Panel Vice-Chairman Howard Eubanks, Dr. Keel and National President C. P. Sander discussing future events of AWS. Dr. Keel's topic at the meeting covered high-quality welding operations in Europe

WELDING OF ALUMINUM

Baltimore, Md.—On the evening of October 18th, 35 members and friends of the *Maryland* Section gathered at the Engineers Club for dinner and listened to a very interesting and informative coffee talk on the construction of the vehicular tunnel being built under the Baltimore Harbor. The talk was given by Bruce Herman, resident engineer on the project, with motion pictures of the work.

Approximately 80 persons were present for the technical talk presented by W. M. Rogerson of the Aluminum Company of America on the topic, "Welding and Brazing of Aluminum." A very interesting talk was presented and was fully illustrated with both slides and a color motion picture. The good and bad features of the various methods of joining aluminum were discussed. The speaker also discussed the weldability, physical data and fabrication problems of various aluminum alloys.

Following a question-and-answer period, an informal session of conversation ensued, fueled by beer and pretzels.

MACHINE TOOL WELDING

Newark, N. J.—The opening meeting of the *New Jersey* Section was held on September 17th at the Essex House in Newark where dinner was enjoyed by 80 members. A short movie was presented entitled "Open Road" which showed the use of steel used in construction of highways and various types of reinforcements. The film was shown through the courtesy of the Bethlehem Steel Co.

Later, approximately 275 members and guests enjoyed a fine talk given by John H. Berryman AWS, manager of Machine Welding Department, Air Reduction Sales Co. His well illustrated talk, entitled "Welding Machine Tools," covered the use of jigs and fixtures used for welding.

The usual after-meeting snack and get-together was enjoyed by all.

STAINLESS STEEL WELDING

Newark, N. J.—The October meeting of the *New Jersey* Section was held at the Essex House in Newark on October 15th. Sixty-three members and guests attended the dinner.

At 8:30 P.M. Program Chairman S. L. Sullivan introduced the speaker for the evening, J. A. Goodford AWS, chief welding engineer for Crucible Steel Company of America, who has been actively engaged in welding for the past twenty-five years, the greater portion of which has been spent developing better methods of welding stainless steels. His long association in this field made him particularly well qualified to talk on this subject, "Welding of Stainless Steel."

Mr. Goodford's talk covered most of the A.I.S.I. type numbers, their particular characteristics and uses in industry. Also the "do's" and "don'ts" in heat treatment of stainless steels and the methods used to prevent carbide precipitation in the welding of unstabilized stainless steels.

Color slides showing pulp mill digesters internally overlayed with Type

STAINLESS-STEEL WELDING IS TOPIC AT NEW JERSEY MEETING

J. A. Goodford (*left*) was the principal speaker at the October 15th meeting of New Jersey Section. Section Chairman E. DiLiberti is at right

A large crowd was on hand to hear a fine paper on "The Welding of Stainless Steels." Some of the attendees are shown during the after-meeting snack and get-together

310 and 316 more than doubled the normal life of these vessels.

PLANT TOUR

Avondale, La.—The *New Orleans* Section had a plant tour of the Avondale Marine Ways as its first meeting of the season on September 28th. Arrangements were made with Henry LeFebre, public relations manager, and R. L. Kitchen, welding engineer.

After meeting in the reception room, appointed guides led small groups through the machine shop, plate dock, layout and fabrication area, sheet metal shop, oxygen producing plant and welding shop with 360 tons capacity turning rolls.

After the tour of the plant, a get-together was held in the reception room where refreshments and snacks were served. Following the refreshments, a 16-mm colored and sound film entitled "Offshore" was shown describing the oil rigs in operation in the Gulf of Mexico.

Following the showing of the film, Bob Flautt, chairman of the Section, expressed his thanks in behalf of the SOCIETY to the Avondale management for the very interesting plant tour.

SELECTING MATERIALS

New York, N. Y.—The second fall meeting of the *New York* Section was held on October 8th at Victor's Restaurant, 1 E. 35 St., New York City, where an excellent dinner was served prior to the meeting.

The speaker of the evening was Harry S. Blumberg AWS, consulting metallurgist, New York City. The topic Mr. Blumberg chose for his talk was "Selection and Weldability of Materials for High-Temperature, High-Pressure Steam Piping."

The speaker discussed the metallurgical approach to selection of materials for modern high-temperature, high-pressure, steam power plant piping. He summarized the steels currently used and analyzed the possibilities of superstrength alloys for high-temperature steam piping, also the weldabilities of such materials.

Mr. Blumberg also discussed materials used at the Eddystone, Pa., plant which is now being built and will operate at 1200° F and 5600-lb pressure, the intent being of producing a kilowatt-hour from $\frac{1}{2}$ lb of coal.

The meeting turned out to be an interesting one with 65 members and guests present.

In addition to the very interesting talk by Mr. Blumberg, a film was shown covering the construction and trial runs of the U.S.S. *Forrestal*, which also was well received by the audience.

NUCLEAR REACTORS

Buffalo, N. Y.—The "Fabrication of a Nuclear Reactor Vessel" was discussed by District Director E. C. Miller, inspection engineer, Union Carbide Nuclear Co., Oak Ridge, Tenn., at the October 24th meeting of the *Niagara Frontier* Section. Mr. Miller described how nuclear history grew from the discovery of radioactivity in 1895, and how the Germans Meitner and Frische started the atom bomb race in 1939 by proposing that neutron bombardment of uranium would cause atomic fission. He explained how construction materials must be selected for their thermal stability, corrosion resistance, low neutron absorption and resistance to radiation damage. He listed typical radiation shielding materials (that is, neutron absorbers) as tungsten, lead, barium, water, iron and concrete. Materials which allow free passage of neutrons are said to have a low absorption cross section (expressed by a small "barns" number) and include beryllium, magnesium, zirconium and aluminum. In this last group, zirconium has good strength and corrosion resistance at 700° F so it was chosen for the spherical core vessel. For the larger sphere or pressure vessel, a stainless-clad carbon steel was chosen for weldability, strength and good heat conductivity. The details of welding both spheres were illustrated by slides. Segments of the zirconium sphere were hot formed at 1200° F from $\frac{3}{8}$-in. plate which had been cross-rolled to reduce directionality of physical properties. The zirconium welds were made by mechanical tungsten-arc process with hand-fed filler rod. Multipass welds gave no trouble despite findings of others to the contrary. Zirconium absorbs gases as readily as titanium; therefore, an inert-gas backing and trailing torch shield were necessary during welding.

ALUMINUM AND ITS ALLOYS

Knoxville, Tenn.—The *Northeast Tennessee* Section welcomed W. N. Rogerson AWS, chief of the Joining Laboratory of the Aluminum Company of America, New Kensington, Pa., as guest speaker for its second meeting of the fall season held at the Regas Restaurant on October 21st. A delicious steak dinner was enjoyed by thirty-three members and guests as a prelude to an exceptionally fine

presentation by the speaker.

Mr. Rogerson's subject was the "Commercially Applicable Methods of Joining Aluminum and Its Alloys." The relatively brief history of the aluminum processing industry was reviewed, with accent on the rapid progress achieved through metallurgical laboratory research. The various processes of joining aluminum by welding invariably poses many problems for the designer and welding operator. These problems were dealt with as each process was discussed and recommendations for their solution given.

The talk was amply illustrated by slides showing welding processes applied to various types of fabrication as well as comparative technical data of alloys. Also shown were slides giving a look at consumable-electrode cutting operations.

The group's interest in Mr. Rogerson's talk was evidenced by the lively question-and-answer period which followed.

CLAD STEELS

Olean, N. Y.—The October meeting of the *Olean-Bradford* Section was held at the Castle Restaurant on October 22nd in Olean, N. Y.

Technical speaker was Louis Keay AWS, technical service engineer, Lukens Steel Co., Coatesville, Pa. Mr. Keay gave a very interesting talk on "Manufacture, Fabrication and Application of Clad Steels" which was very well received. A discussion period followed and Mr. Keay was busy answering questions for a half hour. Members present were from Olean, N. Y., Bradford, Pa., and Little Valley, N. Y.

T-1 STEEL

Peoria, Ill.—The *Peoria* Section met on October 16th at the Mecca Supper Club, where seventy-nine members and guests were present for dinner and meeting.

The technical speaker was Leon C. Bibber AWS, chief research engineer of welding for the U. S. Steel Corp. His subject was "Welding of T-1 Steel and Pressure Vessel Welding and Testing." Mr. Bibber showed slides and motion pictures on characteristics of T-1 steel and the pressure burst tests of pressure vessels. He went into detail on the weldability of T-1 steel and the testing conducted. A long question period followed in which Mr. Bibber answered all questions to the fullest extent.

This was one of the most interesting meetings held by the Peoria Section.

STAINLESS STEELS

Philadelphia, Pa—"Problem Solving in Stainless-Steel Welding" was the subject of a talk at the monthly technical meeting of the *Philadelphia* Section held on October 21st. A last minute substitution resulted in providing a very successful meeting after some earlier misgivings.

Mr. Gordon Parks of the Solar Aircraft Co. had planned to present "Welding's Forward Look" but was suddenly taken ill and was forced to cancel the engagement shortly before the meeting. Philadelphia Section's own R. D. (Dave) Thomas, Jr., president of Arcos Corp., came to the rescue, however, and presented an extremely interesting talk which stimulated a lively discussion.

In the first half of "Problem Solving in Stainless-Steel Welding," Mr. Thomas dwelt upon the difficulties in welded steel piping for high-temperature steam power plants. The use of weld inserts was stressed and was remarkably well illustrated with a colored motion picture. Mr. Thomas discussed the fundamental aspects of stainless-steel welding and brought out the metallurgical problems. A gradual increase in operating temperatures, at approximately 50° F every five years to the present 1100° F has increased the difficulties. He discussed a trend away from the stabilized grades toward the use of the 316 alloy with a 16-8-2 type of filler metal. The results of research by Rensselaer Polytechnic Institute were discussed and illustrated on slides. Several curves and bar graphs showed the ductility at elevated temperatures of stainless steels, types 347, 316, 304 and 304L, and emphasized the advantages of the type 316 stainless steel. In spite of a few problems, however, the power industry has been able to demand twenty years of trouble-free service from its welded piping.

The second half of Mr. Thomas' talk covered the increasing use of stainless-steel overlaying in power plant operation. He discussed the economics as well as the technical aspects in the fields of shielded metal-arc, inert-gas metal-arc and submerged-arc welding. Attention was directed particularly to submerged-arc overlaying, mentioning its many advantages. He stressed the flexibility available through flux design and the ability to make compensations by small additions to the granular flux. Overlays with minimum penetration are being applied to heavy carbon-steel items.

NEW ORLEANS SECTION TOURS AVONDALE MARINE WAYS

Members and guests of the New Orleans Section who visited the facilities of Avondale Marine Ways on September 28th

It was interesting to note that a stainless-steel overlay has been made in the laboratory with all of the alloying elements derived from the flux. Mr. Thomas was quick to point out, however, that this procedure was not sufficiently controllable at present for commercial application.

The Section expressed its gratitude to Mr. Thomas for the excellent talk and wished a speedy recovery for Mr. Gordon Parks.

WELDING CODE REQUIREMENTS

Pittsburgh, Pa.—The regular monthly dinner meeting of the *Pittsburgh* Section was held on October 16th in the Auditorium of the Mellon Institute of Industrial Research. The dinner took place at the Hotel Webster Hall. The subject of the meeting was "How to Meet Welding Code Requirements." A discussion on the "Pennsylvania State Welding Code for Bridge Construction" was held by R. W. Arner, assistant bridge engineer of the Pennsylvania State Highway Dept., Harrisburg. A discussion on the "ASME Pressure Vessel Code" was covered by E. C. Korten AWS, assistant chief engineer of the Boiler Division, the Hartford Steam Boiler Insp. & Ins. Co., Hartford, Conn.

One hundred and twenty-seven members and guests were present at the meeting and many questions were asked on both subjects and answered by the respective speakers.

BUFFALO SPEAKER

Edward C. Miller described the fabrication of nuclear reactor vessels at the October 24th meeting of the Niagara Frontier Section in Buffalo

STAINLESS-STEEL WELDING

Providence, R. I.—In place of a coffee speaker at the October 16th meeting, the *Providence* Section devoted this time to the plans of the Welding Problems Committee. This Committee is to invite welding problems from industries in the Rhode Island Section area. Answers to these problems are to be prepared prior to each subsequent meeting and are to be presented to the members in a well documented and educational fashion. The members of the Committee and the subjects they will handle are as follows: Barry Hackett (Silver Brazing), Steve Hahn (Brazing), Maurice Vanasse (Resistance), T. W. Goodwin (Maintenance), Art Greenhalgh (Nonferrous), Allen Moffett (Steel Fab.), Mr. Mathews (Soldering), Andre Bechard (Metal Spraying), and Carl Rimmler, Chairman.

An excellent talk on "Stainless-Steel Welding" was given by George E. Linnert AWS, manager Welding Laboratory, Armco Steel Corp., Baltimore, Md.

The dinner meeting was held at Johnson's Hummocks and was attended by eighty members and guests.

ANNUAL PLANT VISIT

Painted Post, N. Y.—The 1957–58 season of the *Rochester* Section was opened with a plant visitation to the Ingersoll Rand, Painted Post shops. This was the eleventh annual plant visit made by members of the Rochester Section. About sixty members and guests enjoyed dinner at the Stanton Hotel and then proceeded to the Compressor Fabrication Plant. The tour through the shop included assembly areas, machining and welding, and ended with a visit to the foundry. The evening was extremely interesting and all who attended were amazed at the versatility of this Ingersoll Rand Plant. The machine tools observed are among the finest in the western part of the state, while their foundry produces high-quality castings which weigh from only a few pounds up to many tons.

•

The current season of the Rochester Section will be guided by the following officers and members of the Executive Committee: R. Avery, chairman; D. Masterson, vice-chairman—technical program; R. Cattanach, treasurer; R. Waldvogel, secretary and Educational Committee chairman; S. Evarts, Reception, Attendance and Tickets; J. Beachner, Arrangements (projector, screen, etc.); G. Davies, Entertainment; E. Janes, Mailing; M. Kenney, Publicity, modernize constitution (aided by N. Martin); H. Cleggett, Reception, Attendance and Tickets (deceased); G. Hartwick, Advertising.

Constitutional and appointed members of committee are as follows: W. Dick, reappointed Membership chairman; R. Barr, past Advisory chairman; W. Nash, appointed Dinner Arrangement chairman.

WELDING STEEL CASTINGS

S. Palo Alto, Calif.—The *Santa Clara Valley* Section met on October 22nd at Hal's in S. Palo Alto, with sixty members and guests present for dinner and meeting.

Speaker was W. H. Rice AWS, consultant for the Electric Steel Foundry Co., Portland, Ore. His talk was on "Welding Steel Castings." Dr. Rice had a well prepared talk including much valuable information. He confined his talk to welding stainless-steel castings with information on various types of rod requirements for various cast materials, also the effects and results on heat treating and annealing for welding. The slides covered welding processes and structure of weldment.

A film on manual magnetic-flux gas-shielded arc welding was shown

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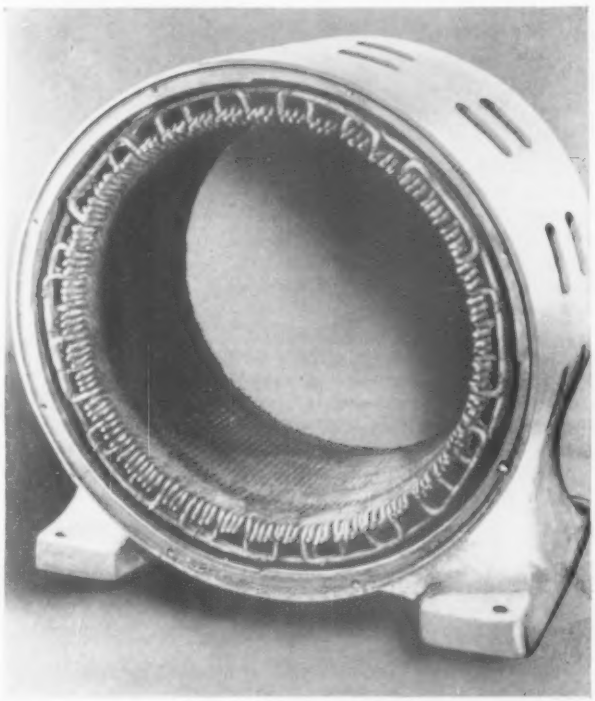

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and was well received. It had been filmed at Caterpillar Corp. in Peoria, Ill.

REACTOR VESSELS

Miami, Fla.—District Director Edward C. Miller, associated with Union Carbide Nuclear, Oak Ridge, Tenn., was the speaker at the October meeting of the *South Florida* Section held on October 16th in the Miami Firemen's Hall.

Prior to the regular meeting, members of the Executive Committee met with Mr. Miller to get acquainted. At 6:00 P.M. all had dinner at the Biscayne Terrace Hotel Dining Room.

Mr. Miller gave a very interesting talk on "Fabrication of a Nuclear Reactor Vessel." His talk took eighty minutes and was followed by a 30-minute discussion.

PLANT TOUR

New Philadelphia, Ohio—On October 9th, ninety-five members and guests of the *Stark Central* Section traveled to New Philadelphia for their regular October meeting. A turkey dinner with all the trimmings was enjoyed at the New Philadelphia Elks Club.

The host, the New Philadelphia Plant of the Warner & Swasey Co., welcomed the visitors through Clayton D. Hatch AWS, works superintendent. He discussed briefly their 1880 Chicago origin and transition to Cleveland, Ohio, products and development of his company. The New Philadelphia plant was established in 1950, manufacturing the internationally known Gradall (ultra flexible, self-propelling, hydraulic operated earthmoving unit), sub items for textile machinery and the Warner & Swasey machine tools. Although relatively new in the area, this plant is already a community leader, and a sustaining member of the Stark Central Section.

At 8:00 P.M. the members and guests adjourned to the nearby plant where they were met by their V.I.P.'s who escorted the visitors in small groups through their plant. They observed machine tools in use, subassembly manufacturing, and welded fabrication for many products; also, the complete manufacture and assembly and a remarkable outdoor demonstration of the Gradall Unit.

The 10:00 P.M. adjournment found the visitors tired, satisfied and with considerable admiration for this organization and its personnel.

RESISTANCE WELDING

Worcester, Mass.—The first meeting of the current season for the *Worcester* Section was held on Monday, October 7th at Nick's Grill. Forty-three members and guests were seated for dinner.

The guest speaker was to have been Ivar W. Johnson AWS, General Electric Co., Schenectady, N. Y. Mr. Johnson was to arrive by plane in the early evening. As fate would have it, this particular night was "ceiling zero" at Worcester Airport, and several others in the New England area.

Mr. Johnson had chosen as his subject "Resistance Welding Fundamentals and Applications"; therefore, it was decided to have someone else talk on resistance welding. Second Vice-Chairman Ed C. Hall of Hall's Inc., proceeded with the program. In this he was ably assisted by John F. Sloan of Whitin Machine Works, the first past chairman of the Section.

Mr. Hall traced resistance welding from its discovery by Elihu Thomson, through its various troubles and phases to the present time. He even dwelled on some of its growing pains. He described the single-phase machine, the three-phase machine, the stored-energy machine, and the various means of control for heat, time and pressure. He described some of the special purpose machines now being used in industry and showed a number of samples of materials and objects difficult to weld.

The audience was very much interested in this subject and the discourse and question period which followed kept the meeting in session until 10:30 P.M.

Aronson GEARED ELEVATION Versus Ordinary Power Elevation

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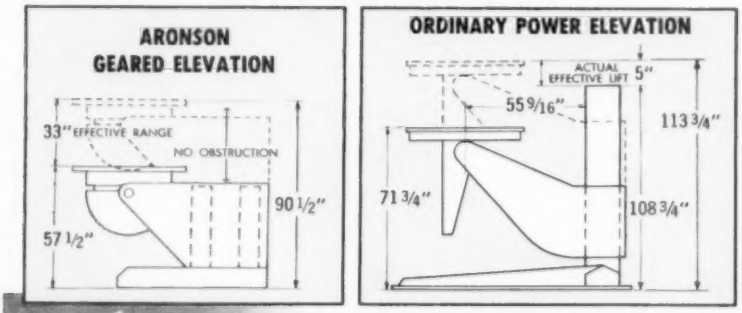

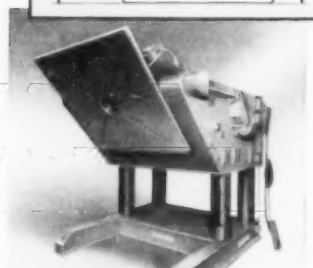

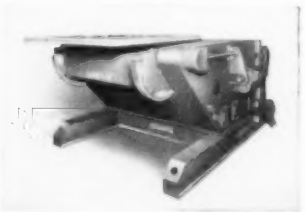

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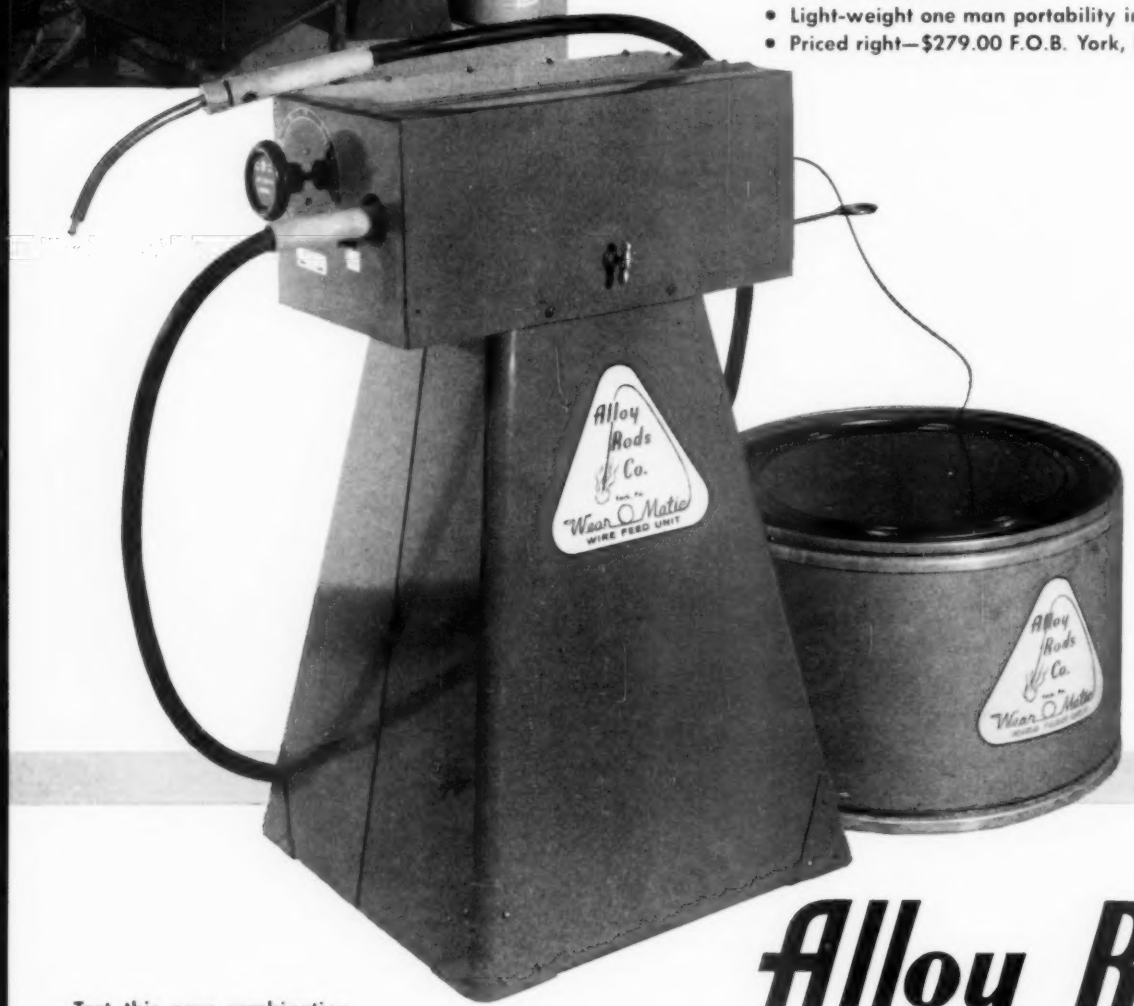

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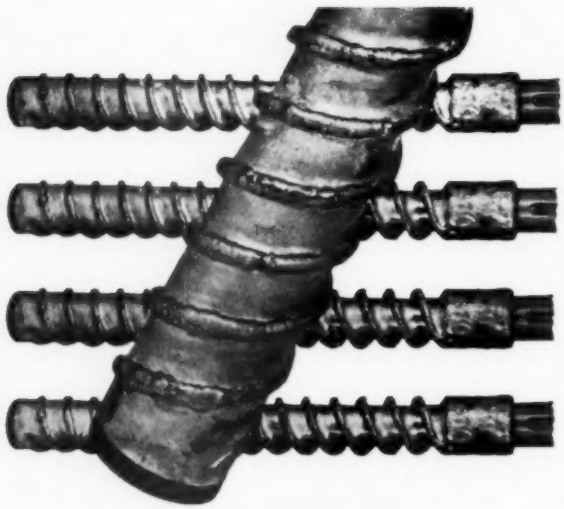

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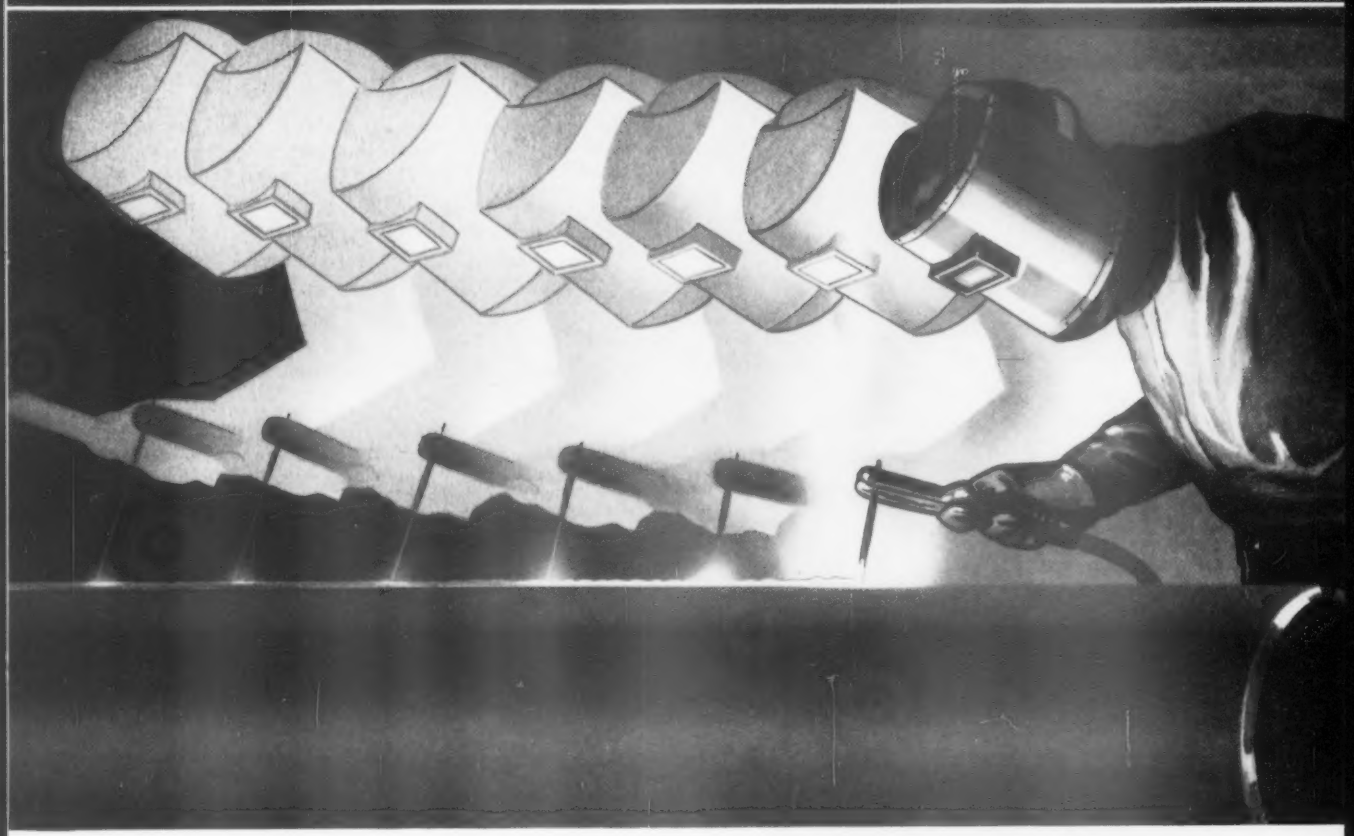

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Current Welding Literature

For copies of articles, write to periodicals in which they appear. A list of addresses is available on request

Ability Testing. Tests for Use in Approval of Welders—Pt 2: Manual Metal-Arc and Oxy-Acetylene Welding of Mild Steel and Low Alloy Steel Pipelines and Pipe Assemblies. *Brit. Standards Instn.*—Brit. Standard (no. 2645) pt. 2, 1956, 63 pp.

Accident Prevention. Effective Control of Welding Fumes. S. E. Nelson. *Instn. Heating & Vent. Engrs.—J.*, vol. 25 (Apr. 1957), pp. 18–25.

Aircraft Manufacture. Fifth Aircraft Production Conference. *Aircraft Production*, vol. 19, no. 2 (February 1957), pp. 56–75.

Aircraft Manufacture. How Grumman Welds Fusion to Non-Fusion Aluminum. J. P. Wright. *Am. Mach.*, vol. 101, no. 11 (June 3, 1957), pp. 104–105.

Aircraft Manufacture. Welding in United States. A. L. Bennett. *Engineering*, vol. 182, no. 4737 (Dec. 21, 1956), pp. 779–780.

Automobile Springs and Suspension. Automation Makes Welding Science. *Can. Machinery*, vol. 68, no. 5 (May 1957), pp. 155–157.

Brazing. How to Silver Braze Powdered Metal Parts. *Industry & Welding*, vol. 30, no. 5 (May 1957), pp. 50–51.

Electrodes, Welding. 22 Ways to Better Low-Hydrogen Welding. D. J. Schaefer. *Power*, vol. 100, no. 11 (November 1956), pp. 122–123, 210, 212.

Footbridges. Welded Aluminum Footbridge. *Engineering*, vol. 183, no. 4750 (Mar. 22, 1957), p. 361.

Houses. U. S. Steel Presents Welded Prefab Home. A. L. Madsen. *Welding Engr.*, vol. 42, no. 5 (May 1957), p. 80.

Inert Gas Welding, Electric Arc. Application of Carbon Dioxide Shielding to Continuous Flux-Covered Electrode Process. P. L. J. Leder. *Brit. Welding J.*, vol. 4, no. 6 (June 1957), pp. 274–281.

Jigs and Fixtures. Positioneering. C. N. Aronson. *Industry & Welding*, vol. 29, no. 10 (October 1956), pp. 148–150, 153–155; no. 11 (November 1956), pp. 70–72, 75–76; no. 12 (December 1956), pp. 106–108, 111–112, vol. 30, no. 1, (January 1957), pp. 100–104; no. 2 (February 1957), pp. 112, 114–115; no. 3 (March 1957), pp. 87–88, no. 4 (April 1957), pp. 142–144; no. 5 (May, 1957), pp. 108–110.

Locomotive Manufacture. Switch to Welding Cut Costs on Circular Parts. R. N. Williams. *Industry & Welding*, vol. 30, no. 5 (May 1957), pp. 62–64, 66, 68–69.

Magnesium and Magnesium Alloys. Magnesium Alloy Castings: Heat Treatment After Welding Repairs. K. Kornfehl. *Can. Metals*, vol. 20, no. 4 (April 1957), pp. 50, 54, 56, 58, 60; no. 5 (May, 1957), pp. 54, 56–61.

Metals Cleaning. Use of Flame-Cleaning. *Corrosion Prevention & Control*, vol. 4, no. 5 (May 1957), pp. 57–58.

Oxygen Cutting Machines. Rail-Mounted Flame-Cutter for Heavy Steel Scrap. *Welding Engr.*, vol. 42, no. 5 (May 1957), p. 73.

Oxygen Cutting. Oxygen Cutting Titanium and Titanium Alloys. G. Coates. *Engineer*, vol. 203, no. 5270 (Jan. 25, 1957), pp. 132–134.

Pipe Lines. Completely Mechanized Pipeline Welding. P. Reed. *Oil & Gas J.*, vol. 55, no. 16 (Apr. 22, 1957), pp. 104–107.

Pipe Lines. Dry Ice Works as Welding Plug. J. D. Lewis. *Oil & Gas J.*, vol. 55, no. 22 (June 3, 1957), pp. 131, 133–134.

Pipe Lines. 15 to 17 Welders Flunked Tests. J. Hinkel. *Gas & Oil J.*, vol. 55, no. 10 (Mar. 11, 1957), pp. 136–138, 140.

Pipe Lines. Pipeline Radiography. H. Hovland. *Brit. Welding J.*, vol. 4, no. 6 (June 1957), pp. 257–260.

Pipe, Steel. New Big-Inch Pipe Mill Is Industry's Showpiece. E. Crawford. *Can. Machinery*, vol. 68, no. 5 (May 1957), pp. 101–105.

Resistance Welding. Resistance Welds Bypass Oxide Barrier. J. J. Obrzut. *Iron Age*, vol. 179, no. 23 (June 6, 1957), pp. 97–99.

Resistance Welding Machines. Automated Spot-Welding Machine Improves Productivity and Quality. J. D. Pinsky. *Tool Engr.*, vol. 38, no. 6 (June 1957), pp. 103–105.

Road Machinery. Typical Operations on Concrete Paver Equipment. J. J. Bognar. *Machinery* (Lond), vol. 90, no. 2323 (May 24, 1957), pp. 1167–1170.

Screw Conveyors. Automatic Weld Setup Eliminates Distortion in Stainless Screws. F. T. Tancula. *Welding Engr.*, vol. 42, no. 4 (Apr. 1957), pp. 39–40.

Shipbuilding Materials. Welding Aluminum-Alloy Deckhouses. W. Muckle. *Brit. Welding J.*, vol. 4 no. 4 (Apr. 1957), pp. 161–167.

Shipbuilding Materials. Welded Aluminum Ship Structures. E. C. B. Corlett, J. F. Leathard. *Shipbldr. & Mar. Engine-Bldr.*, vol. 64, no. 591 (June 1957), pp. 377–383.

Soldering. Successful Soft Soldering of Stainless Steels. *Industry & Welding*, vol. 30, no. 4 (Apr. 1957), pp. 76–78, 116–117.

Testing. Standardization Aids Weld Inspection of Tractors. *Welding Engr.*, vol. 42, no. 4 (Apr. 1957), pp. 47–48.

Testing. Summary of Recent Work on Murex Hot-Cracking Test. P. W. Jones. *Brit. Welding J.*, vol. 4, no. 4 (Apr. 1957), pp. 189–197.

Ultrasonic Welding. Ultrasonic Metal Joining. J. B. Jones and E. E. Weismantel. *Elec. Mfg.*, vol. 59, no. 4 (Apr. 1957), pp. 125–129, 316.

Welded Steel Structures. Resistance Welding for Structurals? *Industry & Welding*, vol. 30, no. 4 (Apr. 1957), pp. 47–50.

Welding. Welding and Brazing Refractory Metals. F. G. Cox. *Steel Processing & Conversion*, vol. 43, no. 3 (Mar. 1957), pp. 147–152, 166; no. 4 (Apr.), pp. 199–204, 226–227.

ABSTRACTS OF CURRENT PATENTS

prepared by Vern L. Oldham

Printed copies of patents may be obtained for 25c from the Commissioner of Patents, Washington, D. C.

2,792,621—Consumable Titanium Electrode—William Howell, Warren, Ohio, assignor to Mallery-Sharon Titanium Corp., Niles, Ohio, a corporation of Ohio.

Howell's patent relates to a laminated, consumable titanium electrode. This electrode is made from a compressed stack of titanium scrap blanks in metal to metal, surface to surface contact. The stack blanks have aligned edges and adjacent blanks are secured together solely by tack welds at their edges.

2,792,626—Welding Back-Up and Method of Applying the Same—John J. Chyle, Wauwatosa, Wis., assignor to A. O. Smith Corp., Milwaukee, Wis., a corporation of New York.

This patent relates to welding a joint between adjacent ends of two tubular members and includes the steps of fitting a continuous fibrous glass backing ring on the outer surface of an expandable chill ring when the chill ring is in its contracted position. Next the chill ring is expanded to stretch the fibrous glass backing ring into engagement with a pair of tubular members adjacent the ends thereof and at the weld joint to be formed therebetween. Thereafter the joint between the two tubular members is welded.

2,792,799—Seam Welding Apparatus—Alfred Dahlstrom, Huntington Park, Calif., assignor to United States Steel Corp., a corporation of New Jersey.

Dahlstrom's novel apparatus is for welding pipes and it includes spaced parallel co-axial supporting rings with beams extending between the rings and spaced circumferentially thereof. An elongated track member carrying an endless chain traversing the exterior and interior sides of each member is provided on the members and the chains include links having blocks with working faces shaped to fit the circumference of a pipe section. The blocks of the inner runs of the several chains constitute an elongated tubular die adapted to embrace a pipe section throughout substantially its entire circumference.

2,793,115—Brazing Alloys—Nikolajs Bredzs and Domenic A. Canonico, Chicago, Ill., assignors, by mesne assignments, to Lithium Corporation of America, Inc., Minneapolis, Minn., a corporation of Minnesota.

A self-fluxing, air-proof brazing alloy is covered in the patent. The alloy contains from about 0.1% to about 2% lithium, and from about 0.3% to about 2% nickel, with a part of the nickel being dispersed in the alloy in the form of finely divided metallic nickel particles. The balance of the alloy consists essentially of silver.

2,793,281—Drilling by Electrons—Karl Heinz Steigerwald, Mosbach, Germany, assignor, by mesne assignments, to Carl Zeiss, Heidenheim (Brenz), Wurttemberg, Germany.

Steigerwald's patent relates to an electron system comprising an electron emitter, means for accelerating the electrons to a relatively high velocity and a control electrode adjacent the electron emitter. Means are provided at the electron emitter for causing the electrons to diverge and thereafter converge to a focus at a remote point from the emitter. A second focusing means is provided for recollecting the electrons into a cylindrical region of increased current intensity for drilling cylindrical holes of certain sizes indicated in the patent.

2,793,282—Forming Spherical Bodies by Electrons—Karl Heinz Steigerwald, Mosbach, Germany, assignor, by mesne assignments, to Carl Zeiss, Heidenheim (Brenz), Wurttemberg, Germany.

This is somewhat similar to Steigerwald's other patent previously listed and it relates to an evacuated vessel having an electron emitter and means for focusing the electron beam from the emitter to increase the current density thereof. Objects to be melted by the electron beam are placed in the plane of maximum current density of the beam and focusing means provide a density of the electron beam at the point of impingement on the objects to cause the objects to be split into a number of smaller objects. The means positioning the objects are adapted to move it in a transverse direction in the evacuated vessel with substantially no loss of vacuum.

2,793,283—Apparatus for Welding Metallic Brake Lining Backing to Brake Shoes and the Like—Samuel K. Wellman, Cleveland Heights, Ohio, assignor to The S. K. Wellman Co., Bedford, Ohio, a corporation of Ohio.

A special pin welding apparatus useful for welding pin ends to brake shoe lining backings is disclosed in the patent. Such pins are used to secure the linings in brake shoe members having holes for receiving the pins therein. Special holding and welding means are provided in the apparatus to perform the specific function and welding action outlined.

2,793,425—Welding Jig—Adolf Koban, Chicago, Ill.

Koban's patent is on a specialized jig for use in repairing railroad sidecar panels to present worn panel surfaces in a flat bottom plane to facilitate puddling of molten welding material on the worn surfaces.

2,794,108—Welding Method and Apparatus—Harwood E. Park, Venice, Calif., assignor of one-third to Gerald H. Peterson, Santa Monica, Calif.

This patent relates to a method for welding together the edges of a longitudinal gap in metal tubing and wherein the gap provides a V-shaped formation. Electrical contacts connected to a source of high frequency current of the order of several thousands of cycles per second are connected to points on the tubing at opposite sides of the gap at a position shortly in advance of the welding point and near the edges. The current is of such high frequency that it flows alternately from one contact to the other substantially following a path from one of the contacts along the surface of one edge of the gap to the welding point along the surface of the opposite edge of the gap to the other contact. The surfaces of the edges are cleaned in advance of the contacts to expose virgin metal at the surface edges. The cleaning, heating and contacting actions are all effected in an inert atmosphere to maintain the edges clean during the heating and welding action.

2,794,109—Apparatus for Metalworking by Electrical Discharge—Albert Martin, Pierrefitte-sur-Seine, France, assignor to Société à Responsabilité Limitée dite: Qualitex, Dunod & Cie, Paris, France.

This patent relates to apparatus for machining a workpiece by spark erosion. A movable electrode is provided and a reversible motor controls the electrode to move it towards or away from the workpiece. Electronic means are provided to generate a train of electrical pulses of controllable duration and other means are connected to cause an arc discharge between the electrode and the workpiece in response to the electrical pulses provided. Another member is present and is responsive to the discharge current to control the generating means to decrease the pulse duration as the discharge current increases and to increase the pulse duration as the discharge current decreases. Other means control the motor means to energize it in one or the other direction as the pulse durations are more or less than a predetermined value.

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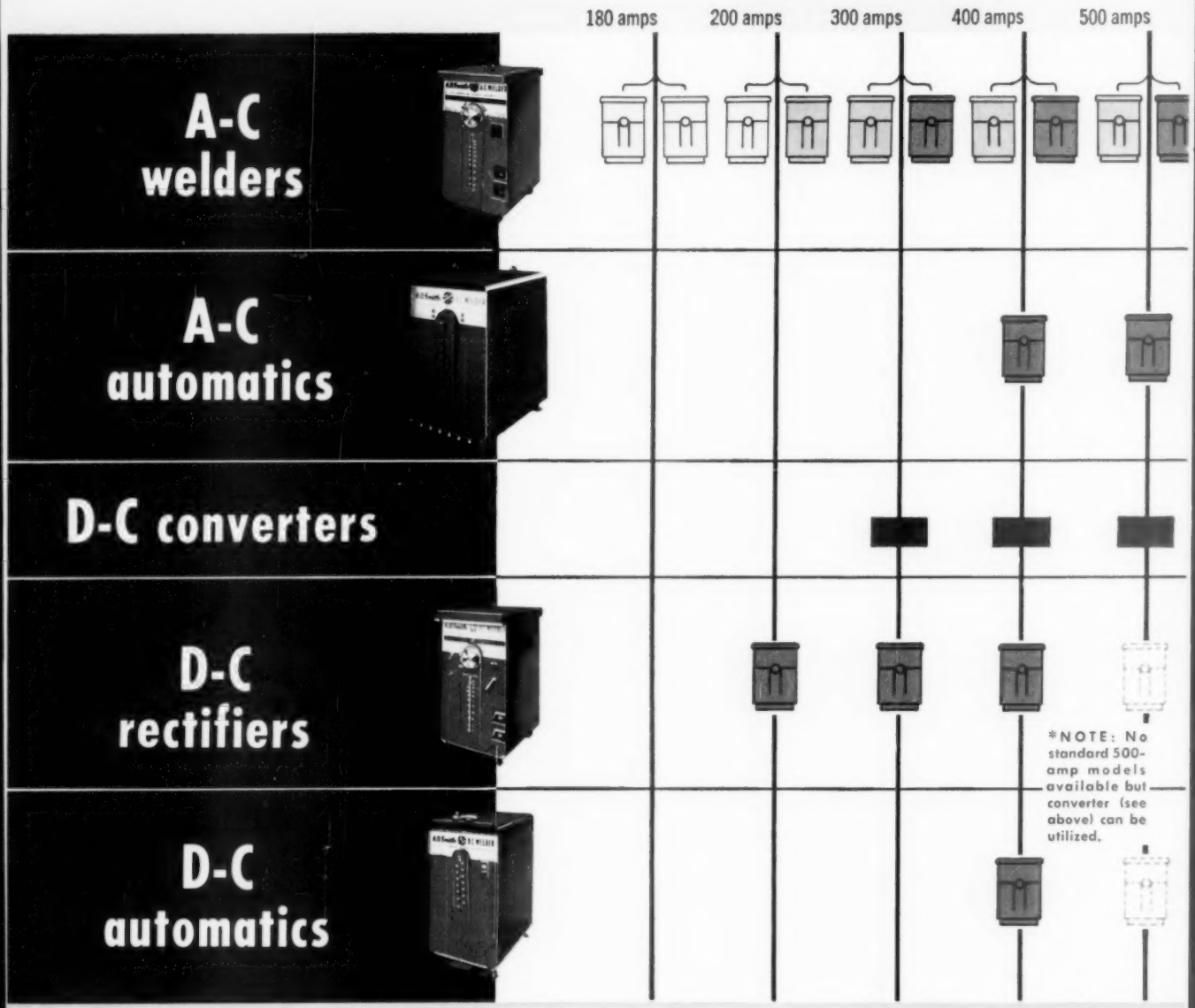

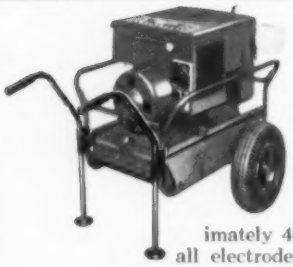

200-amp d-c gas drive — weighs approximately 400 lbs. Handles all electrodes from 1/16 to 5/32 straight or reverse polarity. Can be used as auxiliary a-c power source for lights, power tools, etc.

600 and 1500 constant potentials — 600 amp unit—0 to 45 open circuit volts with fast, easy and precise voltage control. Larger unit offers 80 open circuit volts... handles 10 to 16 welders with grids.

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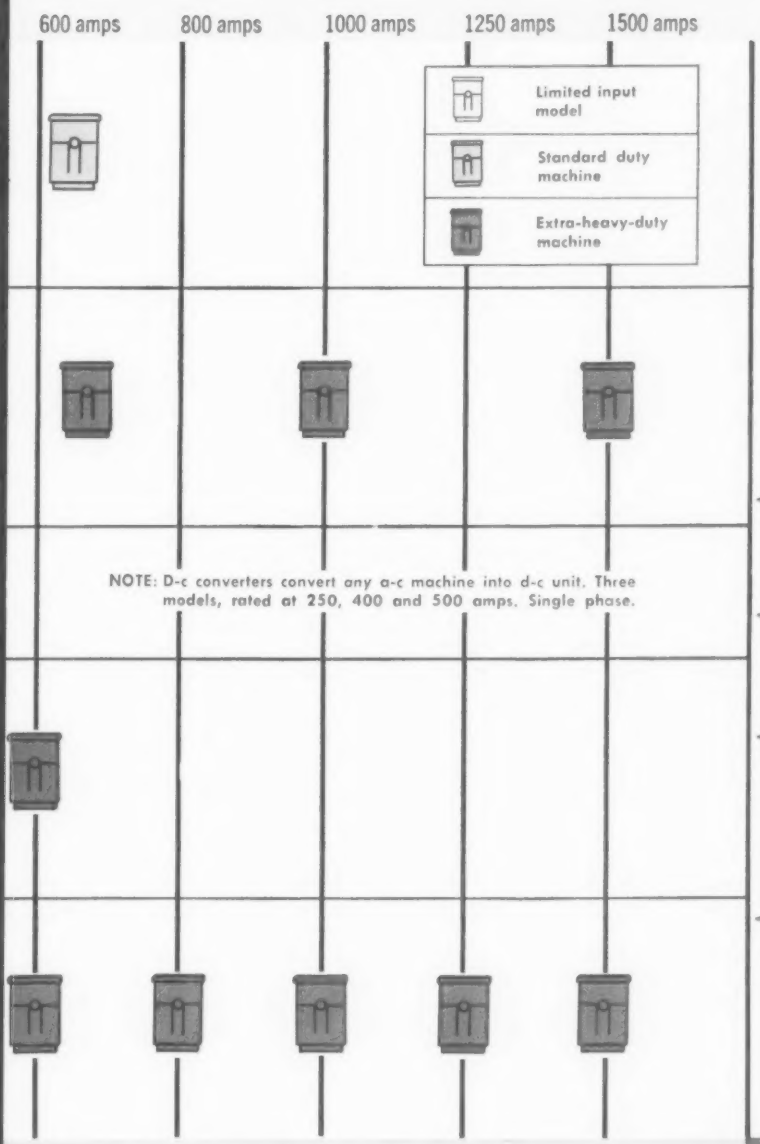
600 amps
800 amps
1000 amps
1250 amps
1500 amps
Limited input model
Standard duty machine
Extra-heavy-duty machine
NOTE: D-c converters convert any a-c machine into d-c unit. Three models, rated at 250, 400 and 500 amps. Single phase.

Limited input models—for farm, shop, maintenance and light-duty repair service — U-180, 180-amp welder and battery charger with dual welding range . . . U-18, same as preceding without battery charger . . . and Model "20S" dual-rated shop welder . . . 200 amps at 50% duty cycle, 295 amps at 20% duty cycle.

"Standard" NEMA a-c welders—Famed A. O. Smith Challenger models in 200, 300, 400, 500 and 650 amp ratings. Last model can be hooked up in series or in parallel. All models except 650-amp unit offer 75 open circuit volts — 650 is rated at 80 open circuit volts.

Extra-heavy-duty a-c welders—This is the elite line of a-c welders, capable of withstanding rough duty that makes other welders fail. All offer full 75 open circuit volts and many other plus features.

A-c automatics — Five basic models . . . 400, 500, 650, 1000 and 1500 amperes. Standard models include primary line contactors. Available with or without automatic/remote current control.

D-c converters — small compact packages quickly and simply convert *any* a-c machine to a d-c unit. Three models — 250, 400 and 500 amps — make *any* machine in your shop a dual welder. A-c or d-c — whatever the job requires.

D-c rectifiers — Here's the most complete line of d-c machines in the industry. All the advantages of m-g sets with none of the maintenance and parts replacement disadvantages. 80 full open circuit volts. Four choices of arc characteristics.

D-c automatics — 6 standard models covering the 400- to 1500-amp range. All feature 80 open circuit volts for more precise arc control regardless of the type of work. Like all A. O. Smith welding machines, they're qualify built in every detail . . . are easy to set up, regulate and work with. Primary line contactor is standard. Automatic/remote current control is optional.

Get the complete story on these A. O. Smith machines by contacting your "man from A. O. Smith" or write direct.

C-OMATIC — A. O. Smith's exclusive CO_2 automatic welding process. CO_2 costs only a fraction of helium or argon . . . can save thousands of dollars annually on gas costs alone. Easily set up, easy to use. Includes control console, remote-control stand, automatic head and special A. O. Smith 600-amp d-c rectifier.

C-OMANUAL — Recently introduced CO_2 hand gun version of C-OMATIC (above) puts manual welding on a virtual mass-production basis. Includes lightweight hand gun which automatically compensates for arc length . . . portable control console and special A. O. Smith d-c rectifier.

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WELDING PRODUCTS DIVISION

Milwaukee 1, Wisconsin

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NEWS of The Industry

Arcflux Opens New Plant

Arcflux Corp., a subsidiary of Arcos Corp., 1500 S. 50th St., Philadelphia 43, Pa. announces the opening of a new 15,000 sq ft, straight-line production plant in Philadelphia to increase production of stainless-steel and low-alloy steel submerged-arc welding fluxes.

R. D. Thomas, Jr., president of Arcflux, stated that the new plant, with air-conditioned offices and laboratories, will more than double the present production facilities.

The modern, one-story brick building is being equipped with mixers and

kiln dryers of the latest design as a means of insuring both high production and a uniform quality product. In order to maintain a continual check on the quality of the stainless-steel and low-alloy steel submerged-arc welding fluxes, the newest type submerged-arc welding equipment is being installed. This will be used not only for quality-control purposes, but also as a customer service.

Test will be made under simulated field conditions with the submerged-arc welding equipment utilizing actual customer materials. In this way, the company maintains that fluxes can be compounded to specific customer needs.

Linde Expands Research Facilities

Plans for new facilities for the Company's Tonawanda Research Laboratories were announced today by W. M. Haile, President, Linde Co., Division of Union Carbide Corp. This expansion is part of Linde's continuous growth in basic research and development in the fields of cryogenics, organic and inorganic chemistry and flame technology.

At the present time a high-pressure laboratory, metallurgical laboratory, a new hydrocarbon storage building and a new services building are to be constructed.

The high-pressure laboratory will reportedly incorporate equipment capable of producing gas and liquid pressures up to 200,000 psi. This is an extension of Linde's interest in high pressure that resulted, in 1940, in the engineering development of the high-pressure process for producing polyethylene. With the increase in pressures available, new research work will be undertaken in the field of chemical reaction and phase transitions at high pressures.

In the metallurgical laboratory new equipment for development of welding procedures on various metals will be made available. Facilities will include a special room for X-ray of metals, a darkroom, preparation room and a metallography room for micrography to determine grain structures of metal.

Air Reduction Sales Hit New High

New highs in sales and net income for the nine-month period ending Sept. 30, 1957, were announced recently by John A. Hill, president of Air Reduction Co., Inc. Net income of $12,390,725 for the first nine months of 1957 was 6.7% over net income of $11,608, 688 for the first nine months of 1956, the previous all-time high. Net income of $4,171,-674 for the third quarter of 1957 was 12.7% higher than net income of $3,702,-955 for the third quarter of 1956.

Machine Design Awards

Tom Learmont, product engineer for Bucyrus Erie Co., Milwaukee, Wis., received the $5000 First Award from the James F. Lincoln Arc Welding Foundation of Cleveland, Ohio, in a national competition sponsored by the Foundation for the design of machines improved through the use of arc welding. Learmont's winning design was for the welded steel base of a 55-cu yd power shovel weighing 452,000 lb. Welding saved 22% in weight, 15% on material costs with a net manufacturing savings of 24%. The cost of stripping coal with the new shovel is reduced an estimated 20%.

A total of 26 awards were made to engineers in companies manufacturing machinery, jigs and tools for various processing type industries. The competition was one in a series sponsored by the Foundation to help advance the progress of welded machine design.

George Volin, design engineer for the E. D. Jones & Sons Co., Pittsfield, Mass., received the $4000 Second Award for the design of a new type of paper-pulp refining machine. The $3300 Third Award went to Leighton W. Johnson, chief engineer for Gunderson Bros. Engineering Corp., Portland, Ore., for the design of a portable gang saw used in the lumber industry.

A total of $25,000 was awarded to engineers from 13 different states, employed in a wide variety of industries. Represented among the awards were machines in the textile, paper, lumber, construction, electronic, elevator, plastic, ceramic, automotive and metal-working industries.

All State Appoints Distributor

An All State Alloy Division has been established by Gordon Duff, Inc., Los Angeles welding and industrial supplies firm, to meet Southern California industry needs for increased inventory stocks at the local level.

Announcement was made by James Duff, company vice-president, following acquisition of exclusive distribution for the Southern California area of the low-temperature alloys and fluxes of All State Welding Alloys Co., White Plains, N. Y.

Federal Welder Acquires Berkeley-Davis

Federal Machine & Welder Co., Warren, Ohio, announces the purchase of a controlling interest in Berkeley-Davis, Inc., Danville, Ill. The Illinois concern will operate as a separate unit, an associate of the parent company, under the present management which consists of John P. Berkeley, president, and Charles H. Davis, vice-president. Berkeley-Davis will continue to manufacture fusion welding machinery which will be sold by the Federal sales organization.

Mr. Berkeley was previously associated with Danville Precision Tool Co. and the Berkeley Equipment Co., while Mr. Davis was formerly welding and project engineer at the Budd Co.'s Red Lion Plant in Philadelphia.

*Oxygen-cutting is speeding metal-working throughout industry. Here a new manual LINDE blowpipe removes a giant riser fast and clean.

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Oxygen-cutting blowpipes are cutting metals of all thicknesses, faster, and more economically than ever before. From one-of-a-kind jobs in small shops, to production line and foundry operations, new high production speeds and gas efficiency have made oxygen-cutting an almost indispensable tool to modern industry.

The new OXWELD C-63 blowpipe shown above is an example of the improved products which result from LINDE's constant research and development in oxygen-cutting. This manual heavy-duty blowpipe will remove even the heaviest risers quickly and smoothly.

For the answer to all your cutting needs—whatever they may be—see LINDE's complete line of oxygen cutting apparatus. Start saving now, contact your local representative today.

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New Liquid Flux Company Formed

Announcement has been made of the formation of a new company, Vap-R-Flux Corp., 198 Wayne St., Mansfield, Ohio, by Cal Walter, president of the firm. Mr. Walter was formerly secretary and general manager of the Gasflux Co. Ralph Raidy, former Gas-

Cal Walter

Ralph Raidy

flux field engineer, becomes Vap-R-Flux's vice-president in charge of sales. Charles P. Feebusch has been retained as consulting engineer. They will manufacture liquid flux and equipment for use in oxyacetylene welding and silver soldering.

The Messrs. Walter, Raidy and Feebusch are members of the AMERICAN WELDING SOCIETY.

Amperex Appoints Representative

Amperex Electronic Corp., Hicksville, L. I., N. Y., manufacturer of electron tubes and semi-conductors, has appointed Mel Pearson & Co. of Denver, Colo., as manufacturer's representative for Utah, Colorado, Arizona and New Mexico. Frank Randall, vice-president in charge of sales for Amperex, made the announcement. Mel Pearson & Co. will cover both distributors and equipment manufacturers.

Burdett Oxygen Becomes A. O. Smith Distributor

The Burdett Oxygen Co. of Cleveland, according to statement released today by E. J. Morse, executive vice-president, has been appointed distributor of welding equipment for the A. O. Smith Corp. of Milwaukee, Wis. Burdett will cover the entire state of Ohio and adjoining counties in Indiana, Kentucky, West Virginia and Pennsylvania.

In his announcement, Mr. Morse pointed out that the A. O. Smith Corp. is not only a manufacturer of welded steel products, but is also one of the world's largest users of welding and for that reason A. O. Smith welding equipment carries the slogan, "made by welders for welders."

Meetings, conferences and study groups of Burdett Oxygen personnel and Smith scientists, technicians and welding engineers have been held throughout the past month. Burdett men also have received first-hand factory training on the Smith welding line at the A. O. Smith welding center.

Transfers Announced by Lincoln

Recent changes in the Lincoln Electric Co.'s district offices have Edwin Williams transferring to Birmingham, Ala.; Bruce N. Frye transferring to Columbus, Ohio; and Gerald R. Stoeckinger joining the district office in Los Angeles, Calif.

Mr. Williams is a native of Louisiana. After serving in the U. S. Navy, he was employed as a welder several years before joining Lincoln, where he taught basic and advanced courses in manual arc welding at the Lincoln Welding School for 7 years. Transferring to sales, Mr. Williams was in Atlanta, Ga., district office for 3 years prior to moving to Birmingham. He is a member of the AMERICAN WELDING SOCIETY.

Mr. Frye transferred to Columbus from Atlanta, Ga., where he had been for 3½ years. Before this, he worked in Lincoln district offices at Kansas City, Mo., and Memphis, Tenn. He was a branch manager of sales for Dictograph Products prior to joining Lincoln. Mr. Frye graduated from the University of Miami, Fla., and served four years with the U. S. Air Force.

Mr. Stoeckinger, a native of Mishawaka, Ind., received a degree in Mechanical Engineering from Purdue University and worked as a junior engineer with the Wheelabrator Corp. before joining Lincoln in 1956. He completed a one-year training course at Lincoln's Cleveland, Ohio, plant before his assignment to Los Angeles.

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CRACKED MOTOR BLOCKS NOW WELDED IN PLACE WITH "LOW AMP" XYRON 2-25

To overcome the difficulties of welding motor block cracks due to freeze or accident, "Eutectic" developed patented Xyron 2-25 (AC-DC), the all-position 'Frigid Arc' coated electrode for cast iron.

Use of all-position Xyron 2-25 (AC-DC) on cracked engine blocks eliminates the need for dismantling and extensive cleaning. Weld may be performed in position.

Xyron 2-25 (AC-DC) meets every requirement for use on cracked engine blocks. Machinable dense deposits can generally be made without preheating the oil soaked cast iron. Weld metal is free flowing and has exceptional affinity for cast iron. This is extremely advantageous when long or large deposits must be made... as it minimizes the possibility of cracking or slag inclusion. The lower amperage permitted with *all* Eutectic "Low Temperature Welding Alloys" eliminates distortion, embrittlement, warpage and danger of fusion.

The result: a lense, smooth, crack free, machinable deposit without the necessity of preheating.

Because of its many specialized features, and because of its strength, (ultimate tensile strength of 56,000 psi), thousands of weldors find it necessary to reach for Xyron 2-25 (AC-DC) when the job is a cracked engine block, transmissions, gear housing, cams, levers, machine bases and similar cast iron parts.

"LOW HEAT" OVERLAY SOLVES ABRASION PROBLEM

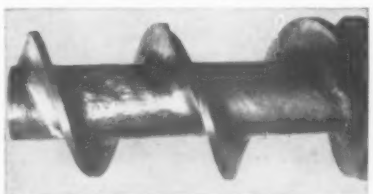
Rough, tough wear and abrasion weakened and finally snapped off flanges on this high-alloyed steel sand and gravel conveyor screw (figure 1). Abrasion also caused pitting and galling. This meant serious maintenance and downtime expenses to management—a West Virginia Mill.

(Fig. 1)

Eutectic's local District Engineer was consulted, and suggested rebuilding the screw with EutecBor #9.

EutecBor #9 is a super-high alloy overlay specifically formulated for use where severe abrasion is a problem. It is non-magnetic in nature and has a hardness as deposited of RC 55-62. EutecBor #9 is also extremely resistant to corrosion and has the added advantage of minimizing weld weakening dilution of the base metal. Deposits of this widely useful alloy accept a high polish and resist pitting and galling (figure 2).

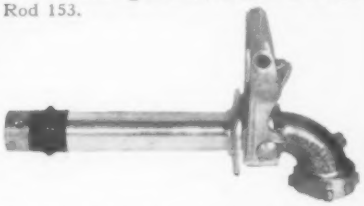
Management now reports conveyor shaft stays in operation much longer without maintenance—effects a considerable savings in downtime and repair costs.



(Fig. 2)

ALUMINUM TO STEEL JOINT "INDESTRUCTIBLE"

An Iowa manufacturer of oil equipment wanted a lighter, stronger fill tube. A steel tube encased in an aluminum tube (except for the very tip) was to be welded to the valve apparatus, a casting of Almag 35 Aluminum. The manufacturer's Chief Research Engineer was told such a weld was impossible. His local "Eutectic" District Engineer recommended testing a procedure utilizing EutecRod 19 and EutecRod 153.



The valve casting was machined to permit a one-inch insertion of the steel tube.

Joining would be done with EutecRod 19—a self-fluxing, low-melting, solder-type alloy.

EutecRod 153 was chosen to "tin" the steel tube; it has a high affinity to EutecRod 19.

The tubes were cleaned and dipped in the molten EutecRod 153. The high remelt then enabled the insertion of the tube in the Almag casting, and the flow of EutecRod 19 through the joint without burning or reaching the oxidation point of the "tinned" surface on the steel tube. Subsequent destruction tests showed that the Almag casting was completely destroyed, or the steel tube was bent so badly that the part would have been unusable, and yet there was no rupture of the joint area.

SEASON'S GREETINGS

With this issue, we come to the conclusion of the first year of publishing Eutectic Welding News. We trust the articles contained on these pages have proven to be of value. We will strive to continue presenting new cost and time saving ways of using 'Low Temperature Welding Alloys.'

As 1958 quickly approaches we wish to take this opportunity of extending to you Season's Greetings, and Best Wishes for a Happy and Prosperous New Year.

"EUTECTIC" WELDING HEADLINES • TIME-MONEY-MACHINERY SAVERS

Automatic Welding of Aluminum Pipe

At a recent aluminum clinic, co-sponsored by Reynolds Metals Co. and the Maracaibo chapter of the American Institute of Mining, Metallurgical and Petroleum Engineers, in Maracaibo, Venezuela, a demonstration was made of an automatic machine capable of welding aluminum pipe.

The machine was given its final field tests recently near Corpus Christi, Texas, under the direction of Charles Bruno, chief welding engineer for the Reynolds firm. The machine reportedly welded four miles of 4-in. Schedule 4 aluminum pipe (Alloy 6061T6) in a gas-gathering system with satisfactory results.

During this operational test the new machine made the dramatic record of welding 2880 ft of the pipe in a 4-hr period, with no supplemental hand welding needed at any point. This means an average of 18 satisfactory welds every hour.

Welding and other technical aspects of aluminum applications in the petroleum industry are of special interest in the Lake Maracaibo area now. The world's first aluminum-jacket off-shore oil drilling platforms were installed here recently.

In addition, the first full-scale installation of underwater aluminum flow lines in Lake Maracaibo is being made by Creole Petroleum Corp. For a portion of this installation Reynolds Metals is supplying 17,000 ft of 8.625-in. Schedule 40 aluminum pipe. This is said to be the largest diameter aluminum pipe to be used for flow lines. The Creole project will use 200,000 lb of Reynolds aluminum.

Machine Design Seminars

Machine designers from 11 different states and 14 different companies recently spent five days at the plant of the Lincoln Electric Co. in Cleveland, Ohio, discussing better ways to design and fabricate welded machinery. The occasion was the second machine-design seminar sponsored by Lincoln.

The seminars have been so productive that Lincoln has announced dates for additional meetings and invites the participation of machine designers interested in the design or redesign of weldments. The seminar discussions and lectures cover the advantages of welding and how to apply them, determining loads, selecting efficient sections, designing welds, relating designs to efficient production methods, calculating weld strength, designing low cost welding, estimating and other related subjects and problems introduced by participants. Problems studied are both redesigns of castings to weldments and new designs of weldments.

Dates for the scheduled seminars are November 11–15, January 13–17 and February 24–28. A small registration fee is charged. Further information may be obtained from Robert Wilson, Director of Application Engineering, the Lincoln Electric Co., Cleveland 17, Ohio.

Liquid Oxygen Propels Redstone

Air Products, Inc., Allentown, Pa., together with the U. S. Army Corps of Engineers have developed a million-dollar battlefront industrial plant on wheels that can produce liquid oxygen

QUICK way to cut downtime!
ECONOMICAL, too!
REBUILD
Worn Tractor Grousers
with
SS HI-C
TRACTOR GROUSER BARS
SPECIAL ANALYSIS HIGH CARBON STEEL

Attaches quickly with any good grade of low hydrogen electrode.
Easy to attach with any manual or automatic electric welding method.
Write for complete details and nearest distributor.
MEMBER
SOLE PRODUCERS
STULZ-SICKLES CO.
PORT AVENUE at JULIA ST. ELIZABETH, NEW JERSEY

For more details, Circle No. 18 on Reader Information Card

CANCELLED DUES

The attention of each member of the SOCIETY is invited to Article IV, Section 4 of the SOCIETY's By-laws which reads in part as follows:

> "Any Member or Associate Member who shall have paid his dues for thirty-five (35) years, or who shall have paid his dues for thirty (30) years and reached the age of sixty-five (65) years, shall thereafter be exempt from the payment of further dues, except that the number of years for which dues were paid as an Associate Member shall be reckoned as nine-tenths (9/10) of their number in the above provisions. (Student Membership years not included.)"

If you, as a member of the SOCIETY, should be and wish to be exempt from further dues payment in accordance with the foregoing by-law ruling, kindly so notify National Headquarters.

F. L. PLUMMER
National Secretary

from common air in quantity to help power the Army's Redstone and other missiles through space. The first plant to be delivered under current contracts was publicly displayed for the first time at an Army exhibition for the Association of the United States Army, beginning on Oct. 27, 1957, at Fort Myer, Va.

The 20-ton plant, developed by Air Products, Inc., is mounted on four semi-trailers. It is designed to produce 20 tons, or about 80 barrels, per 24-hr day of 99.5% pure liquid oxygen when operated at normal atmospheric pressure in air of 50% relative humidity. It will operate in outdoor temperatures ranging from 125° above to 25° below zero Fahrenheit. It uses about 920 lb of diesel fuel per hr and yields about 2 lb of liquid oxygen per lb of fuel oil consumed.

Engwald Moves Their Operations

Engwald Corp., manufacturers of systems to exhaust noxious fumes during welding, have moved to a larger facility at 125 Sheridan Blvd., Inwood, Long Island, N. Y.

ARIZONA TEENAGERS WIN WELDING AWARDS

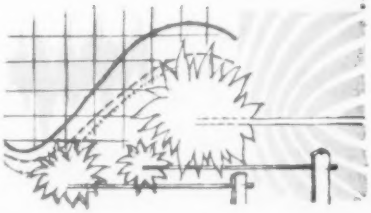
Gil V. Dye, Jr., president of Phoenix Welding Supply Co., poses with the top winners in the welding contest sponsored by his company. Shown (*left to right*) are: Mr. Dye; Pat Franklin, second place; Ralph Wong, first place; and Dennis Harman, third place. The contest was held in Prescott, Ariz., in conjunction with the annual meeting of the State Future Farmers of America

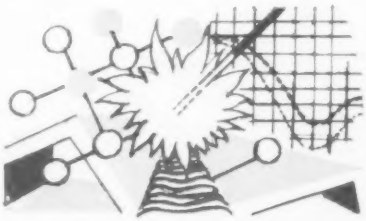
CRACKING Problems with 316 and 347 Stainless?

CHAMPION'S

16-8-2 Electrodes Offer freedom from CRACKING

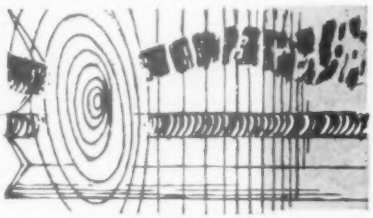
HERE'S WHY: New CHAMPION 16-8-2 Stainless Electrodes have a composition which has much higher hot ductility than any other grade of stainless. Produces freedom from cracking in weld, zone of fusion, or parent metal.





HERE'S WHY: Tests reveal that this composition is not subject to embrittlement on aging, and possesses very good stress-to-rupture properties.

HERE'S WHY: Lime type coating deposits extremely clean, sound weld metal. Handles well in all positions. Low spatter. Easy slag removal. Smooth, even and finely rippled weld bead.



Excellent mechanical properties are accomplished with CHAMPION 16-8-2 Welding Electrodes:

Yield	61,000 psi
Tensile	92,000 psi
Elongation in 2"	50%
Reduction of area	61.8%

The chemistry is closely controlled to produce less than 4% ferrite in the deposit.

Typical chemical analysis is as follows:

Carbon .08	Chromium 16.19
Manganese 2.24	Nickel 8.00
Silicon .37	Molybdenum 1.79

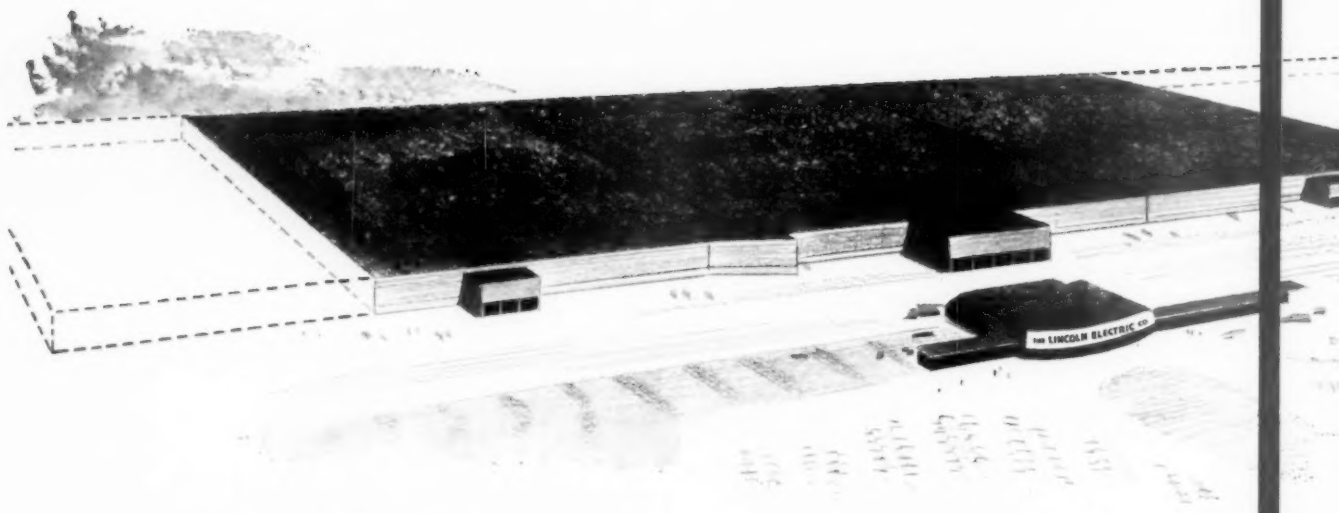
Other stainless requirements: CHAMPION offers a complete line of stainless electrodes in a full diameter range from 5/64" to 1/4", lime or AC-DC coated.

FOR FULL DETAILS on CHAMPION'S 16-8-2 or other stainless electrodes write to:

The **CHAMPION** Rivet Co.

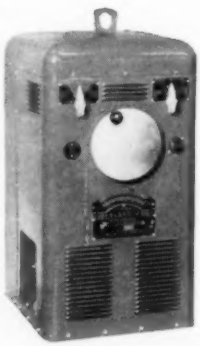
Cleveland 5, Ohio • East Chicago, Indiana

For more details, circle No. 19 on Reader Information Card

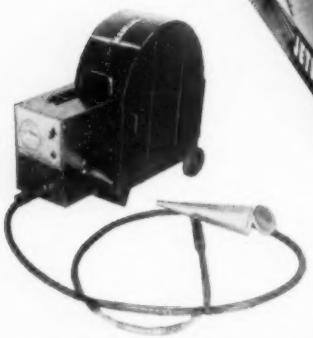


Lincoln's 60% plant expansion
makes it now, even more, the... **RELIABLE**

ELECTRODES



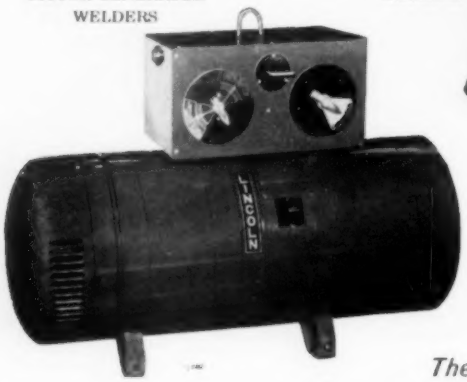
TRANSFORMER-RECTIFIER WELDERS

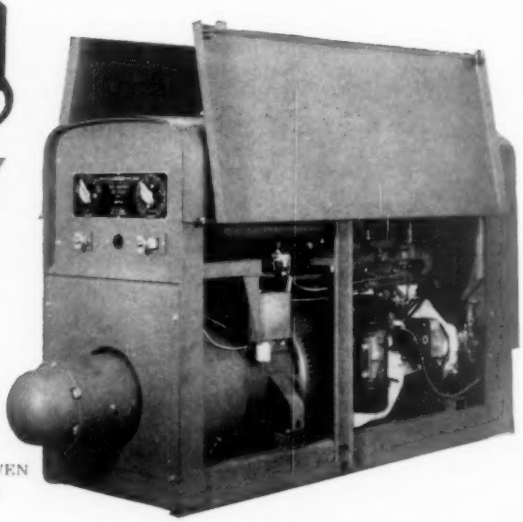


SEMI-AUTOMATIC WELDERS

AUTOMATIC WELDERS

MOTOR-GENERATOR WELDERS

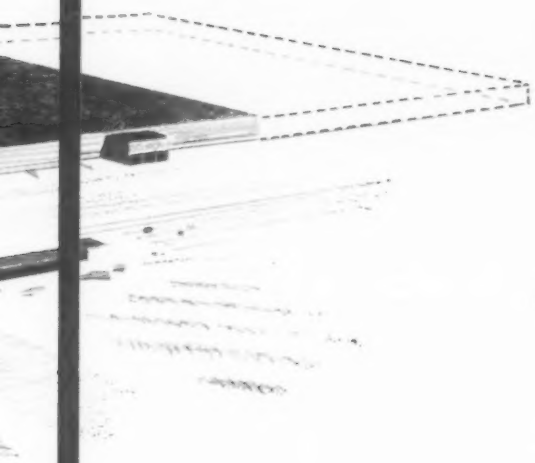




ENGINE-DRIVEN WELDERS

The World's Largest Manufacturer of Arc Welding Equipment

For more details, circle No. 20 on Reader Information Card



For over 50 years Lincoln's sole purpose has been to provide the arc welding industry with a complete line of top quality products . . . at the lowest possible cost.

SINGLE SOURCE SUPPLY

for all your Arc Welding needs

Today, in spite of rising prices, Lincoln equipment and products while maintaining high standards of quality, cost less than 30 years ago.

The Lincoln line includes transformer-rectifier, motor-generator, engine driven and automatic and semi-automatic welders in capacities to suit the needs of the home craftsman or the largest industry.

Lincoln has been first with cost cutting advances in arc welding electrodes. Iron powder electrodes that cut welding time as much as 30% were a Lincoln first. Lincoln Fleetweld 5, the most outstanding of all mild steel electrodes when first developed, is still an all time favorite. Lincoln research continues to improve existing electrodes and develop new electrodes as new applications arise.

New 60% expansion of Lincoln's still young (5 year old) plant assures industry of a supply line that won't run dry.

To help you apply these products to best advantage Lincoln maintains the largest and best trained welding sales force in the country. Lincoln welding engineers maintain offices in 54 cities throughout the United States and are only hours away from any welding problem.

30 warehouses, strategically located across the country, assure rapid delivery of Lincoln products.

No orphans, Lincoln machines are serviced in 220 field service shops by factory trained mechanics with genuine Lincoln parts. And Lincoln's factory rebuild program offers complete reconditioning of any welder regardless of age and condition at a fraction of replacement cost.

Lincoln can bring you superior products and better service at less cost because welding is our primary business—not a sideline.

Bulletins on any type of arc welding equipment and electrodes are available. Write—

LINCOLN

THE LINCOLN ELECTRIC COMPANY

Dept. 1736 • Cleveland 17, Ohio

For more details, circle No. 20 on Reader Information Card

PERSONNEL

Low Promoted by Chapman Valve

The appointment of Sidney Low as director of research for the Chapman Valve Manufacturing Co. was announced recently by C. Goodwin Carter, president.

He succeeds Dr. Vincent T. Malcolm, who retired.

Mr. Low, who has been chief of research and technical control, has been with the company since 1941, the year he received a B.S. degree in Mechanical Engineering from Rensselaer Polytechnic Institute.

A member of the AMERICAN WELDING SOCIETY, Mr. Low is presently director of District 1.

Westendarp Appointed by Airco

Henry O. Westendarp, former New York district manager with the General Electric Co., has been appointed manager of arc welding sales for the eastern region of Air Reduction Sales Co., it was announced by A. S. Blodget, Jr., regional sales manager.

Mr. Westendarp, past chairman of the Northern New York section of the AMERICAN WELDING SOCIETY, has been active in the welding industry for twenty-five years. He has won the

Henry O. Westendarp

Coffin Award, GE's highest employee recognition, for outstanding engineering and commercial contributions to the welding industry; and the Wilson Gold Key Award.

Mr. Westendarp will have headquarters at Air Reduction's main offices in New York City.

Other former members of GE's welding staff who have joined Airco's sales force, as a consequence of GE's recent withdrawal from the manufacture of arc welding equipment and electrodes, are W. G. Leman, at Buffalo; Walter Roe, Jr., at Philadelphia; and Richard Nowell, at Jersey City.

Calhoun Appointed by Bastian-Blessing

The Rego Division of The Bastian-Blessing Co. has announced the promotion of J. K. Calhoun to the position of sales manager in charge of the High Pressure Gas Equipment Division. This division handles the sale of gas welding and cutting equipment, gas

J. K. Calhoun

plant equipment, cylinder valves, manifolds, oxygen therapy equipment and custom-made equipment.

Mr. Calhoun has been associated with the high pressure gas industry for 18 years, nine of which have been spent with The Bastian-Blessing Co. He is a director of the Chicago section of the AMERICAN WELDING SOCIETY.

Cavanagh Promoted by Alloy Rods

J. O. Cavanagh has been elected to the post of vice-president in charge of research at Alloy Rods Co., York, Pa., it was announced today by E. J. Brady, president of the firm.

Mr. Cavanagh was formerly director of research and development. He is a graduate of Illinois Institute of Technology, where in 1933 he was awarded a Master's Degree in Chemical Engineering.

Prior to joining Alloy Rods Co. in

J. O. Cavanagh

1951, he was associated with the Hollup Division of National Cylinder Gas Co., where in 1936 he began his career in welding research.

Mr. Cavanagh is a member of the AMERICAN WELDING SOCIETY, American Society for Metals and the Pennsylvania Society of Professional Engineers. He is currently serving on the Welding Specifications Committee of the AMERICAN WELDING SOCIETY and is a past director of the York Section of the SOCIETY.

Marr Named by Westinghouse

Charles W. Marr has been appointed sales representative at the Pittsburgh office of Westinghouse Electric Corp.'s welding department, according to an announcement by F. J. Purdy, manager of marketing for the department. In his new post, Mr. Marr will be responsible for advising Westinghouse customers on current welding problems and for informing them concerning new welding products and techniques developed by Westinghouse.

Active in the welding field since 1936, Mr. Marr was formerly associated with the Westinghouse manufacturing laboratory in Pittsburgh. He is a member of the AMERICAN WELDING SOCIETY.

Oechsle and LeFevre Promoted by Metalweld

S. John Oechsle, Sr., president of Metalweld, Inc., Hunting Park Ave. & Fox St., Philadelphia, Pa., has an-

For more details, circle No. 21 on Reader Information Card ⟶

USS TECHNICAL WELDING DATA

5

Welding Tests on USS "T-1" Steel

Reported here are the results of underbead cracking tests made on ½" plates of USS "T-1" Steel. Details of test specimens are shown in Fig. 1. Welds were made at an initial temperature of 70°F. using E-6010 and low hydrogen electrodes.

Results of cracking tests are shown in the table at right. Note that in the specimens welded with E-6010 electrodes a great amount of cracking occurs. However, the specimens welded with low hydrogen electrodes show little or no underbead cracking. It is suggested, therefore, that only low-hydrogen-type electrodes be used for the welding of "T-1" Steel.

A hardness survey of an underbead-cracking specimen welded with an E-12015 electrode is shown in Fig. 2. Note that the peak hardness obtained at the immediate junction of weld metal to parent metal is about 420 DPH. This hardness is unaffected by changes in type of electrode.

Table showing susceptibility of ½-inch thick "T-1" Steel to underbead cracking (Heat 74L236)

Initial Plate Temp., °F	Per Cent of Underbead Cracking*		
	E-6010 (Cellulose Type)	E-12015 (Low Hydrogen Type)	E-9015 (Low Hydrogen Type)
0	23	3	0
70	54	1	0

*Average of five tests

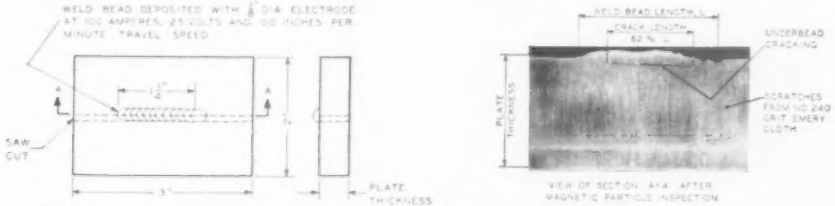

WELD BEAD DEPOSITED WITH 5/32" DIA. ELECTRODE AT 150 AMPERES, 25 VOLTS AND 10 INCHES PER MINUTE TRAVEL SPEED
SAW CUT
PLATE THICKNESS
WELD BEAD LENGTH, L
CRACK LENGTH, 52% L
UNDERBEAD CRACKING
SCRATCHES FROM NO 240 GRIT EMERY CLOTH
PLATE THICKNESS
VIEW OF SECTION A-A AFTER MAGNETIC PARTICLE INSPECTION

Fig. 1. Typical underbead cracking specimen of USS "T-1" Steel welded with E-6010 electrode.

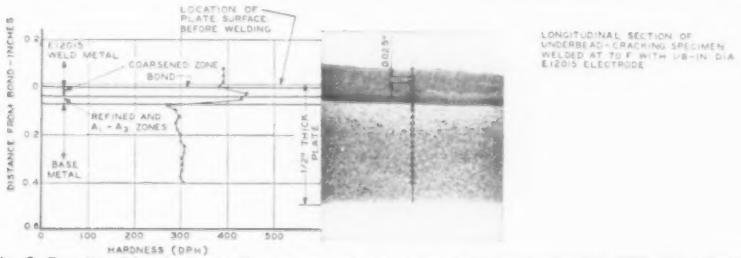

LOCATION OF PLATE SURFACE BEFORE WELDING
E12015 WELD METAL
COARSENED ZONE
BOND
REFINED AND A1 - A3 ZONES
BASE METAL
1/2" THICK PLATE
DISTANCE FROM BOND - INCHES
HARDNESS (DPH)
LONGITUDINAL SECTION OF UNDERBEAD-CRACKING SPECIMEN WELDED AT 70°F WITH 1/8-IN. DIA. E12015 ELECTRODE

Fig. 2. Results of hardness studies on an underbead cracking specimen—½" USS "T-1" Steel.

REMEMBER THIS: No other alloy steel offers the combination of properties that "T-1" Steel possesses. Here, in just one steel, you get very high yield strength (90,000 psi minimum), extraordinary toughness, great resistance to impact abrasion, and good high temperature strength. These let you reduce the size of highly stressed parts . . . save weight, reduce the amount of welding required and cut your costs. USS "T-1" Steel is being used in bridges, excavating equipment, pressure vessels, towers . . . in equipment that must take heavy abuse in sub-freezing temperatures . . . in equipment that must withstand heavy stresses and impact abrasion at temperatures up to 900°F.

WRITE FOR COMPLETE INFORMATION about the application and fabrication of USS "T-1" Steel. United States Steel, Room 2801, 525 William Penn Place, Pittsburgh 30, Pa.

USS "T-1" CONSTRUCTIONAL ALLOY STEEL

USS and "T-1" are registered trademarks.

United States Steel Corporation, Pittsburgh • Columbia-Geneva Steel Division, San Francisco • Tennessee Coal & Iron Division, Fairfield, Ala.
United States Steel Supply Division, Warehouse Distributors, Coast-to-Coast • United States Steel Export Company, New York

UNITED STATES STEEL

nounced the appointment of Vice-President S. John Oechsle, Jr. to executive vice-president of the Corporation. Kenneth G. LeFevre, formerly sales manager of the Protective Coatings Division, has been made vice-president of the firm. Metalweld, Inc. is composed of three divisions, Construction Equipment Division, Protective Coatings Division and Industrial Welding Division, all located in Philadelphia, Pa.

The Messrs. Oechsle, Sr. and Jr. are members of the AMERICAN WELDING SOCIETY.

Glenn E. Smith

Smith and Flint Appointed by Tweco

Glenn E. Smith, former West Coast district manager for Tweco Products, Inc., has been transferred to the general office in Wichita, Kan. Mr. Smith joined Tweco in 1950 and has worked in various departments of the company. In his new position, he will serve in the Sales Promotion and Advertising Department.

Fred W. Flint has been appointed district representative covering the state of California. Mr. Flint, a graduate of the University of California, has been given this appointment following factory training and field service the past year.

Messrs. Smith and Flint are both members of the AMERICAN WELDING SOCIETY.

Fred W. Flint

Brown Named by Welder Service

The Welder Service Co., 2037-41 Canton St., Toledo 2, Ohio, announces the appointment of D. L. Brown to its sales and service staff. Mr. Brown was a sales engineer for the Ohio Belting and Transmission Co. for the past eight years.

Mr. Brown, previous to that, was active both in the technical and managerial end of the welding supply field some years ago, having been owner of the old Industrial Gas Distributors Company of Toledo.

James Follas has been assigned to handle inside sales and engineering and act as office manager of the Welder Service Co.

Giles Appointed by Pureco

Donald C. Giles, formerly branch manager of Pure Carbonic Co.'s Seattle district, has been appointed district manager at Berkeley, Calif.

Mr. Giles joined Pureco in 1946 as a salesman at Berkeley. In 1955, after a period of military service, he transferred to Seattle in the sales capacity, and was made branch manager in 1956.

Pure Carbonic Co., a division of Air Reduction Co., Inc., is a major producer of carbon dioxide in liquid, gaseous and solid ("Dry-Ice") forms for wide applications in industry.

Averbeck Joins Alloy Rods

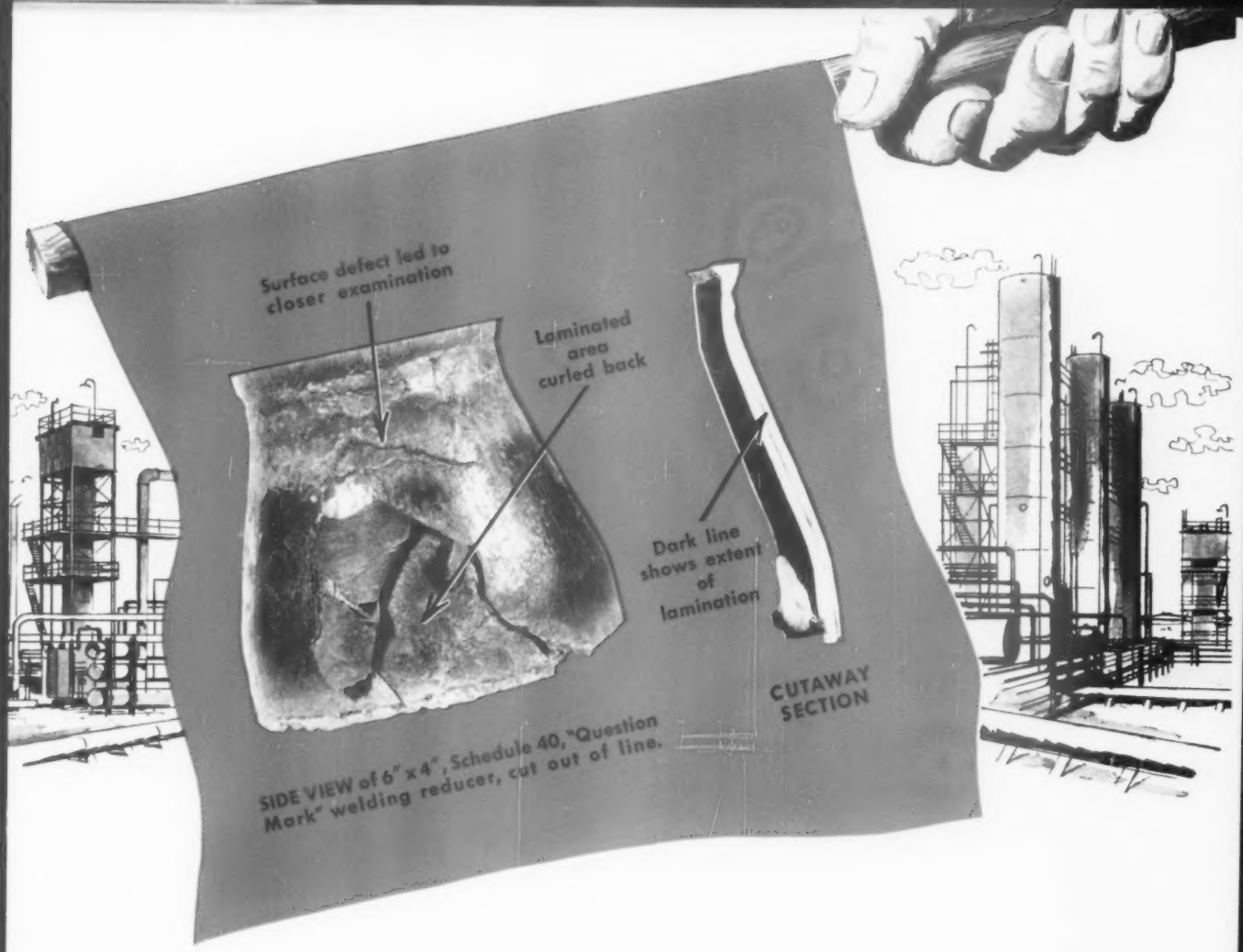
A. A. Averbeck joins Alloy Rods Co.'s sales organization as a field representative and will work from the com-

A. A. Averbeck

Alloys & Fluxes for joining ALL METALS ALL METHODS
TORCH WELDING
SOLDERING • FILLING • SEALING
TORCH BRAZING
FURNACE BRAZING
ARC WELDING
WEAR PROBLEM... INSIDE OR OUTSIDE. ONE SOLUTION!
ALL-STATE
NO. 13 NICKEL SILVER BUILDUP ROD
ALLOYS All-State FLUXES
for welding • brazing • soldering • tinning • cutting
Users Report on Cams: "Using your No. 13 rod to build up such surfaces, we have had 3 to 5 times the cam life."
Users Report on Wrist Pin Holes in 500-lb. Pistons: "No. 13 enabled successful repair where 200 degrees more heat would have spoiled everything. There was no warpage."
For Instruction Book on 62 alloys and fluxes write All-State Welding Alloys Co., Inc. White Plains, N. Y.
ALL-STATE ALLOYS AND FLUXES
REQUEST COMPLETE LIST OF THESE PRODUCTS FOR PROBLEM SOLUTIONS

For more details, circle No. 22 on Reader Information Card

Circle No. 23 on Reader Information Card →


Surface defect led to closer examination
Laminated area curled back
Dark line shows extent of lamination
CUTAWAY SECTION
SIDE VIEW of 6" x 4", Schedule 40, "Question Mark" welding reducer, cut out of line.

Watch out for the after-costs of Question Mark fittings!

Unknown fittings may look like a bargain on the price tag, but watch out for the consequences!

Surface defects led to the above "Question Mark" fitting being cut from the piping. Further examination showed the steel inside was laminated. Pieces cut out literally fell apart. Here was an open invitation to serious trouble . . . lost production, wasted dollars and possible human casualties.

This is another example of a dangerous situation posed by unknown fittings of questionable quality . . . a serious threat to the safety and economy of well-engineered piping.

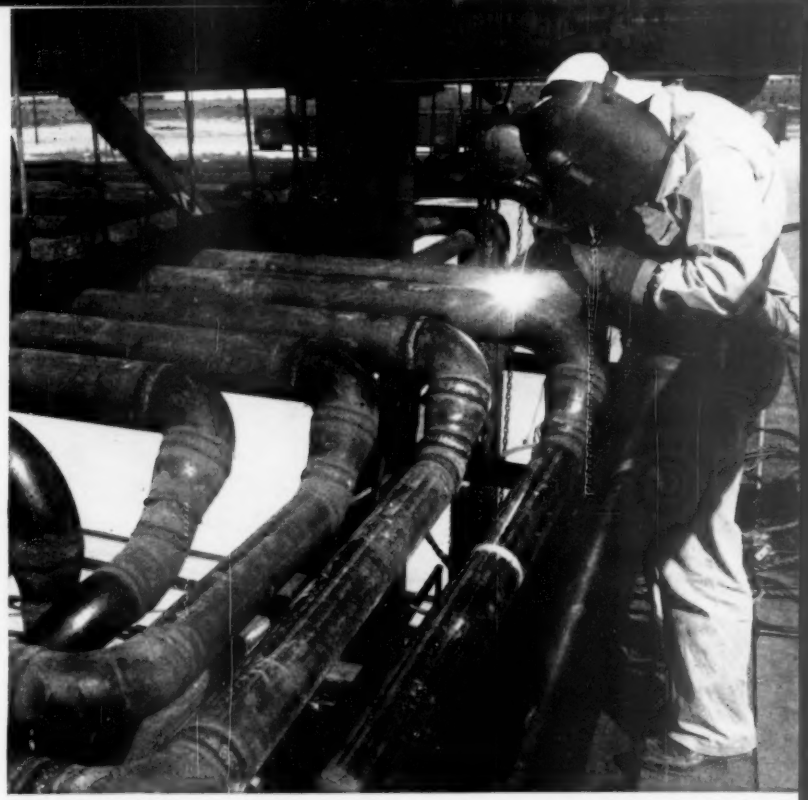
You can avoid these risks by specifying KNOWN fittings!

DANGER! *Your first warning of Question Mark fittings is their lack of complete, permanent identification of manufacturer, wall thickness, weight, material . . . as required by A.S.A. code.*

A message in the interests of top quality piping . . . by Tube Turns, Louisville, Kentucky

YOUR SAFEGUARD

Safeguard your piping investment with known fittings!

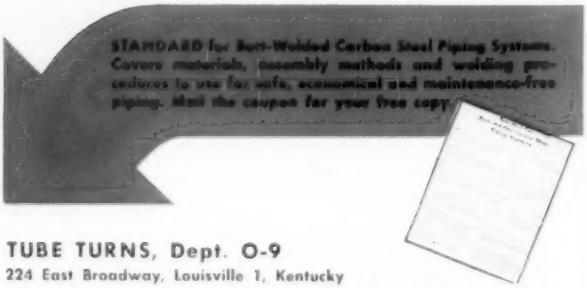


TOP QUALITY! *Directional and size changes in this process piping are made with* TUBE-TURN *Welding Elbows and Reducers . . . recognized for their unsurpassed uniformity and quality.*

The cost of fittings is a small fraction of the total cost of a piping system. To buy "cheap" fittings and run the risk of impairing the performance of your entire system can, therefore, be "penny wise and pound foolish."

When you specify and buy TUBE-TURN* products, you know your investment is safeguarded by unsurpassed quality of fittings and flanges. They meet all American Standard and Safety Code requirements. Each product is permanently marked with complete size and material designation.

COMPLETE LINE! *Your nearby Tube Turns' Distributor gives you prompt delivery from the complete line of more than 12,000 Tube Turns' stocked items. Photo courtesy The Ross-Willoughby Co., Columbus, Ohio.*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pany's new Houston, Texas sales office and warehouse. He will also work with distributors in eastern Texas and western Louisiana. Prior to joining the York, Pa. firm, Mr. Averbeck was a sales representative for the Welding Division of General Electric in the Houston area. He is a member of the AMERICAN WELDING SOCIETY and the American Society for Metals.

Chamberlin Named by Essex

John B. Chamberlin has been appointed vice-president in charge of sales of the Essex Welding Equipment Corp., 17–19 Tichenor Lane, Newark

John B. Chamberlin

5, N. J., according to an announcement by A. C. Axtell, president of the firm.

Mr. Chamberlin has sold his interest in Interstate Welding Supply Corp., an organization he had served as president, to the Southern Oxygen Co. He has been active in the sale of welding equipment and supplies for the past 20 years in northern New Jersey and metropolitan New York. Mr. Chamberlin is a member of the AMERICAN WELDING SOCIETY.

McNally to Head Arcflux

James P. McNally has been named product manager of the newly-opened

James P. McNally

Philadelphia plant of the Arcflux Corp., subsidiary of the Arcos Corp.

Mr. McNally was formerly superintendent with Union Tank Car Co. Previous to that he was sales manager, Bart Manufacturing Corp., Belleville, N. J., and production metallurgist, Carrier Corp., Syracuse, N. Y. He is a member of the AMERICAN WELDING SOCIETY, the American Society for Metals, the American Society for Testing Metals and the American Ordnance Association.

The Arcflux Corp. produces stainless-steel and low-alloy steel submerged-arc welding fluxes.

Dennison Re-elected

The Metal Spraying Corp., 3600 W. Pierce St., Milwaukee, Wis., announces that Peter G. Dennison, president and founder of the Metal Spraying Corp., has been re-elected president of the American Metallizing Contractors Association for the third consecutive term.

His company has been nominated as a member of the Metco System Contractors group, a nation-wide group of firms having the qualifications and facilities necessary to meet requirements in the field of corrosion prevention.

The Metal Spraying Corp. has also been granted licenses to do "Metcolizing," in Wisconsin, a special patented process for the protection of steel against heat corrosion.

OBITUARY

Marguerite M. Kelly

Miss Marguerite M. Kelly, Secretary Emeritus of the AMERICAN WELDING SOCIETY, passed away at her home in Parkchester, N. Y., on Tuesday morning, October 22nd, following a heart attack. She was in her sixties.

A native of New York City, Miss Kelly received her business training at Columbia University. Afterwards she joined a group from Columbia whose assignment it was to assist a visiting Italian Aviation Commission during World War I. The Commission, under the command of Major Perfetti, toured the United States to inspect American methods and equipment.

In 1918, Miss Kelly accepted a position as secretary to Dr. Comfort Avery Adams. As a result, she became acquainted with the activities of the Welding Committee of the Emergency Fleet Corp., of which Dr. Adams was chairman.

From 1919, the year the AWS was founded, until 1949, the year of her retirement as secretary, Miss Kelly was a staff officer of the SOCIETY. After serving as assistant secretary from 1919 to 1920, she was appointed acting secretary. Miss Kelly remained in this capacity until 1922 when she was elevated to the post of secretary, a position she held until her retirement. In 1937 she was given the additional responsibility of assistant treasurer.

During her thirty years with the SOCIETY, Miss Kelly assisted 23 presidents and 6 treasurers. Also, she was

Welding Engineer

Duties—Working with AWS technical committees in gathering and correlating technical data; preparing minutes, reports and other records of committee activities; editing standards for publication as completed.

Disseminating technical information in answer to inquiries from industry.

Qualifications—Ability to work with technical men at all levels in a cooperative manner.

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instrumental in speeding the establishment of AWS Section organization and contributed heavily to the development of Section procedures and operations. In addition, Miss Kelly acted as secretary of a number of standing committees, including the post of secretary of the Convention Committee.

In the course of her long tenure in office, the budget grew from $18,500 in 1923 to over $288,000 in 1949. The founding membership of 217 increased to 8000 during World War II.

On May 13, 1949, the AWS Board of Directors through a special by-law change, created the position of Secretary Emeritus, and appointed Miss Kelly to the post. In this capacity she served as a consultant to the Society, drawing from her years of experience within the organization. Miss Kelly held the title until her death.

William F. Johnson

William F. Johnson, 62, died accidentally during a hunting excursion in Idaho on October 6th.

Mr. Johnson was president of John-

William F. Johnson

son Welding Equipment Co., Chicago, Ill., a firm founded by him in 1920. The welding supply house has been in continuous operation since its inception. Mr. Johnson was active in the Chicago Section of the American Welding Society.

Paul Dyer Merica

Dr. Paul Dyer Merica, former president of International Nickel Co., Inc., died on October 20th at the Phelps Memorial Hospital in Tarrytown, N. Y. He lived at Millwood, N. Y.

Dr. Merica was president of International Nickel Co. of Canada, Ltd., and its United States subsidiary, the International Nickel Co., Inc., from 1952 to 1954. He also served as a director for the aforementioned organizations, American Metal Co., Ltd., Babcock & Wilcox Co., and Whitehead Metal Products Co., Inc.

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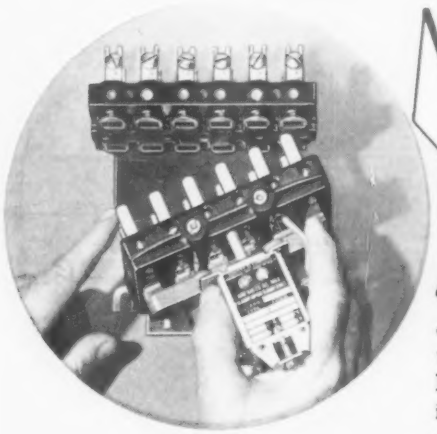

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are of special rugged industrial design and construction. Flexibility provided by plug-in feature (on both sequencing relays and timers), permits easy circuit changes without complete controller redesign.

Write for Bulletin 8991
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For more details, circle No. 26 on Reader Information Card

NEW PRODUCTS

Utility Welder

Miller Electric Manufacturing Co., Inc., of Appleton, Wis., announces a new farm and general utility-type welder designated as M-180-P. Continuous, precise and fingertip current control is reportedly provided by new movable shunt regulator. Amperage indicator

on panel gives correct setting for each job.

Other features include: two welding current ranges; power factor correction for full compliance with REA requirements; extra-heavy gage steel body with baked enamel finish. The unit weighs 137 lb.

Standard equipment includes 6 ft of 3-conductor primary cable with 3-prong plug and wall receptacle; 20 ft of No. 4 electrode cable with electrode holder; 15 ft of No. 4 ground cable with clamp; welding helmet and 5 lb of assorted electrodes.

For more details, circle No. 27 on Reader Information Card.

Iron-Powder Electrode

Metal and Thermit Corp., Rahway, N. J., announces the availability of Speedex Triplex, a heavily-loaded iron-powder electrode which reportedly offers high manual welding speeds approaching those of automatic equipment. Designed for downhand welding with either drag or open arc technique, this new electrode is said to deposit 16 lb or more of weld metal per hr. Speedex Triplex is specifically designed for downhand welding of large fabrications such as ship sections, freight cars and tanks. Available in $^1/_4$ in. diam only, the electrode is used at currents as high as 500 amp. Using the drag technique, $^3/_8$-in. positioned fillets may be made while $^1/_2$-in. fillets may be produced with open arc.

According to the manufacturer, Triplex operates equally well with ac or dc, has good arc characteristics and an easily removed slag. Welds produced have ultimate strengths of 60 to 65,000 psi combined with elongations of from 30 to 33%.

For more details, circle No. 28 on Reader Information Card.

Welding Positioner

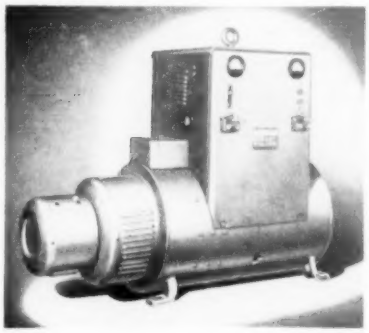
Aronson Machine Co., Arcade, N. Y., now manufactures a new type of geared-elevation principle in their heavy-duty Model GE250 welding positioner. This machine has a weight capacity of 25,000 lb with the center of gravity location of the work 12 in. above the table and 12 in. off-center. Thirty-three in. of geared elevation at 20 ipm will lift full load at

90-deg tilt of the table. The geared-elevation principle consists of a 4-post elevator base having 10-in. OD x 1-in. wall seamless tubes with spur-rack teeth for lift pinions. Each post has four concave rollers to maintain rigidity and steadiness of the chassis while elevating. The cross-sectional column of the base measures 47 x 78 in. All elevator mechanisms including the columns are reportedly contained inside the chassis with nothing extending up above the top of the chassis to obstruct the turning of large weldments.

For more details, circle No. 29 on Reader Information Card.

Carbon-Air Cutting Machine

Hobart Brothers Co., Troy, Ohio, has added a 1200-amp model to its line of "Carbonaire" machines specially designed as a power source for the carbon-arc and compressed-air method of cutting and gouging all kinds of metals.



The new machine is rated 1200 amp on 100% duty cycle and has a maximum output of 1600 amp. The 900-amp model is recommended for carbon electrodes up to $^1/_2$ in. in diam and the new 1200-amp model is recommended for carbon electrodes over $^1/_2$ in. in diameter.

The manufacturer reports that a single rheostat gives a wide range of voltage control. This along with the self-regulating features of the carbon electrode, provides control for all sizes of carbons used in carbon-arc and compressed-air cutting and gouging. Ammeter and voltmeter are optional equipment.

For more details, circle No. 30 on Reader Information Card.

Welding Flux

The Weldrod Department of Ampco Metal, Inc., 1745 S. 38th St., Milwaukee 46, Wis., has recently produced a new welding flux known as Ampco-Braz Flux #2—suitable for general brazing, cast-iron welding and cast-iron brazing with the oxyacetylene process.

According to the manufacturer, several of the outstanding advantages of Ampco-Braz Flux #2 are (1) excellent wettability, (2) non-fuming and non-toxic, (3) ability to depress filler metal bubbling and fuming, (4) deep penetra-

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MILD STEEL, LOW HYDROGEN AND HARD-FACING
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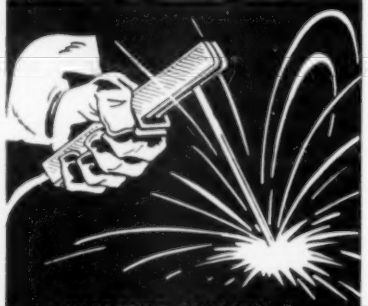

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Circle No. 32 on Reader Information Card

tion, providing strong joints, (5) protection against excessive oxidation, (6) dissolves and removes oxides formed, (7) provides dense, sound deposits, and (8) easily removed from deposit.

Packaged in one-pound tins, Ampco-Braz Flux #2 is available from Ampco weldrod distributors throughout the country or from the manufacturer.

For more details, circle No. 33 on Reader Information Card.

Inert-Gas Welding Control

The development of a new weld-cycle control unit designed to provide programmed control of all functions of machine inert-gas welding is announced by Air Reduction Sales Co., a Division of Air Reduction Co., Inc., 150 E. 42nd St., New York 17, N. Y. The unit consists of a main panel which contains all of the adjustable control mechanisms, and a push-button remote control station.

The new system is for use with high-frequency current and d-c straight-

polarity welding power from a saturable-reactor-controlled rectifier-type supply. Designed for applications requiring precise weld timing and crater filling on repetitive circumferential or longitudinal welds, it reportedly simplifies the arc welding of production items such as canteens and transistor cases.

The manufacturer discloses that the various timing mechanisms of the control are set in advance to meet the requirements of the job. Each operation of the weld start switch initiates the entire weld program, which automatically progresses until the weld is completed and the crater filled.

For more details, circle No. 34 on Reader Information Card.

Alloy Electrode

An improvement in the coating of All-State No. 275, a chromium-nickel electrode, has resulted in the elimination of weld porosity, provides denser deposits and minimizes spatter, according to All-State Welding Alloys Co., Inc., White Plains, N. Y. This new electrode replaces one manufactured since December 1954, carrying the same designation. The old electrode is discontinued.

Welded properties of All-State No. 275 are said to include: tensile strength, 120,000 psi; elongation in 2 in., 35%; and Brinell hardness, 200. The a-c, d-c electrode also meets such specifications as MIL-E-6844-E, AMS-5785-B and MIL-E-16715-A.

For more details, circle No. 35 on Reader Information Card.

Surfacing

Eurekalloy "C," a new nickel base, chrome, tungsten, molybdenum electrode for hard surfacing equipment and dies which are subjected to extreme heat and abrasion, has been developed by Welding Equipment & Supply Co., 5225 E. Davison Ave., Detroit 12, Mich.

Eurekalloy "C" is said to have a welded hardness of approximately 230 Brinnel and excellent machining qualities.

For more details, circle No. 36 on Reader Information Card.

High-Temperature Flux

The research laboratories of American Products Corp., 422 S. Dearborn St., Chicago 5, Ill., have recently developed a high-temperature flux for brazing steel, stainless steel, nickel alloys, high-temperature alloys, copper, tungsten and chromium carbides with silver-brazing alloys.

This new flux is reportedly suitable for use with torch, induction, air-gas or furnace brazing. Fluidity temperature of the Xcel-Flux "NF" is said to be reached at 900° F and remains active up to 3000° F.

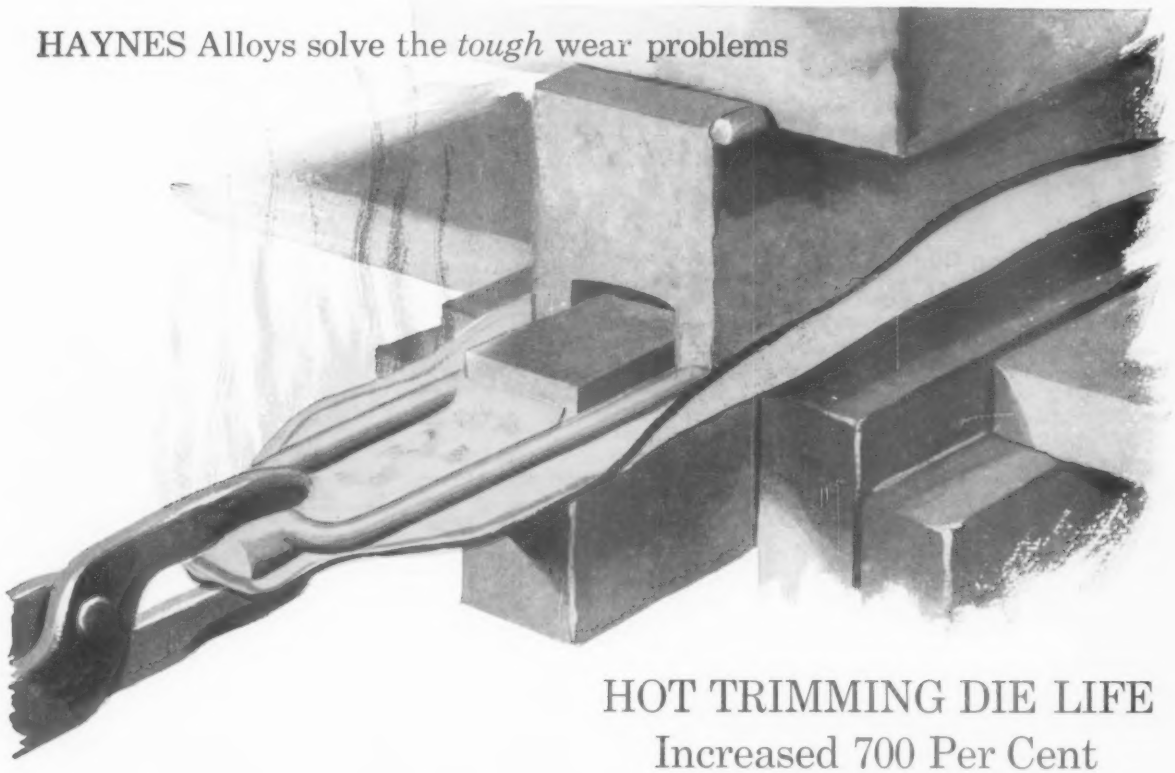
According to the manufacturer, at high temperatures this flux protects metal surfaces from oxidation and dissolves all oxides that form during brazing, including chromium oxides.

For more details, circle No. 43 on Reader Information Card.

Packaging for Spooled Wire

Ampco-Trode grades 10, 40, 160 and Phos-Trode bare wire when supplied on either spools or rims are now being packaged in heavy-duty, clear plastic bags prior to insertion into the outer fiberboard shipping containers, according to an announcement by Ampco

HAYNES Alloys solve the *tough* wear problems



HOT TRIMMING DIE LIFE
Increased 700 Per Cent

HAYNES hard-facing alloys resist the sudden shock of impact and the softening effects of heat . . . two characteristics that make them unusually successful in extending the service life of hot-working equipment. In one plant, hot-trimming dies hard-faced with a HAYNES cobalt-base alloy removed the flash from 25,000 parts before they had to be reconditioned. This was a 700 per cent increase in service life over unprotected dies. In this instance the parts were heated to 2000 deg. F just prior to the trimming operation.

If you have a problem involving a combination of heat and impact, straight abrasion, or corrosion, you will find that there is a HAYNES hard-facing alloy that can solve it . . . economically. The hard-facing deposit will increase the service life of the part and, because of its superior wearing qualities, permit you to use a less expensive base material.

Write for literature or call one of our sales offices. HAYNES STELLITE COMPANY, Division of Union Carbide Corporation, Kokomo, Indiana. Sales offices in Chicago, Cleveland, Detroit, Houston, Los Angeles, New York, San Francisco.

This trimmer die, being touched up with a HAYNES nickel-base alloy, has trimmed over 20,000 parts. The hard-facing alloy is tough, machinable, and can be applied to all common die steels by the metallic-arc process.

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ALLOYS

HAYNES STELLITE COMPANY
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The terms "Haynes" and "Union Carbide" are registered trade-marks of Union Carbide Corporation.

For more details, circle No. 37 on Reader Information Card

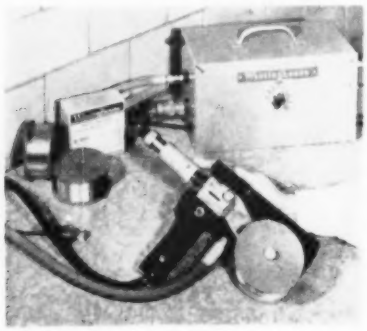
Metal, Inc., 1745 S. 38th St., Milwaukee 46, Wis.

The plastic bags are of sufficient length so they can be reused in the event the spools or rims are stored between jobs.

For more details, circle No. 38 on Reader Information Card.

Inert-Gas Welding Gun

A portable handgun and control for welding aluminum and other metals has been developed by the arc welding department of the Westinghouse Electric Corp., Pittsburgh, Pa. Able to handle filler wire down to 0.020 in., it is

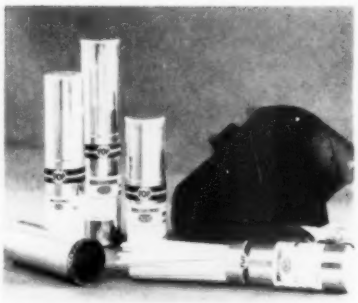


reportedly the first fully-portable gun capable of welding light gage metals; it is particularly effective in welding aluminum. It is also said to be the first commercially available gun to mount an integral motor-driven wire drive and an integral wire supply. Two models will be available: one will handle filler wire in $^{1}/_{50}$ (0.020) to $^{3}/_{64}$ in. diam; the other is for wire in $^{3}/_{64}$ to $^{1}/_{16}$ in. diam.

For more details, circle No. 39 on Reader Information Card.

Aluminum Cans for Electrodes

A new aluminum can which reportedly provides maximum product



protection and greater consumer convenience is now being used by the Air Reduction Sales Co. to package its stainless-steel electrodes.

The aluminum can, manufactured by Kaiser Aluminum & Chemical Corp., 1924 Broadway, Oakland 12, Calif., is a seamless, two-piece container which seals the electrodes from dampness and moisture.

Airco's new "Pop" can, so called because of the sound made when the top section of the container is removed, represents one of the first commercial applications of aluminum cans in the United States. It was produced by Kaiser Aluminum's newly-developed technique of can-making to produce a seamless can body and bottom in one piece.

According to the manufacturer, the top section of the "Pop" can is flared slightly at the rim to assure a snug friction fit, and a waterproof, airtight industrial tape completes the hermetic seal. When the required number of electrodes are removed for use, the container can be resealed with the tape, thereby protecting the unused electrodes indefinitely.

The "Pop" cans are $2^{3}/_{4}$ in. diam. They come in three different sizes to conform to standard electrode lengths: 9 in., containing 6 lb of electrodes; 12 in. containing 8 lb and 14 in., containing 10 lb. Since the can opens in the middle, its two parts are of equal length.

For more details, circle No. 40 on Reader Information Card.

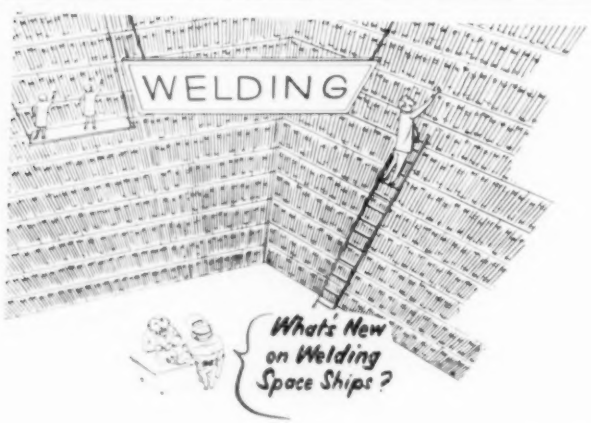
Mild Steel Electrode

A new electrode for use with small-transformer power sources in the all-position welding of light-gage mild steel has been developed, according to an announcement by Air Reduction Sales Co., a Division of Air Reduction Co., Inc., 150 E. 42nd St., New York 17, N. Y. The Airco 90C is designed to provide good penetration at rapid travel speeds.

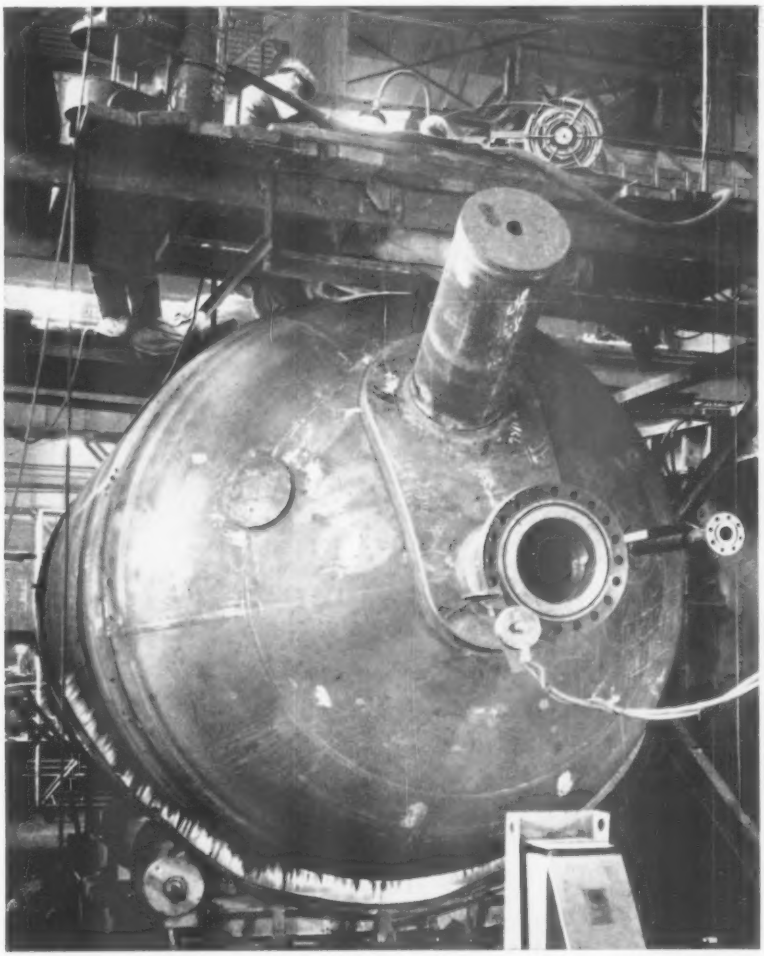
The 90C reportedly features the easy-starting tip that arcs immediately under low open-circuit voltage. The arc is quiet and steady and the coating aids in controlling metal transfer. Complete slag coverage is maintained without arc interference.

The manufacturer states that the deposit meets X-ray standards for this type of electrode. Physical properties of the deposit, tested in accordance with AWS specification A5.1–55T, are: tensile strength, 76,400 psi; yield strength, 66,500 psi; elongation in 2 in., 24.5%; and reduction of area, 51.0%.

This new electrode can be used in such applications as the welding of storage tanks, gear guards, metal furni-



The Welding Journal provides the most complete library of information on the art and science of welding available . . . anywhere. If you have a product for the welding or allied industries, the Journal's pages will reach your market.



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When inspection by X-ray is required, don't gamble . . . rewelding is expensive . . . specify Drawalloy "quality controlled" wire. *Drawalloy* stainless steel welding wire is produced to strictly controlled specifications to provide the right chemistry, finish and temper for smooth operation in your equipment and to provide X-ray quality welds.

Why not discuss your stainless welding wire needs with your *Drawalloy* Distributor or Representative . . . a man ready to help you. Bulletin 355-DC provides complete information on every grade of *Drawalloy* wire. Write to: Drawalloy Corporation, Lincoln Highway West at Alloy Street, York 13, Pennsylvania.

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THE WIRE MILL FOR THE WELDING INDUSTRY — STAINLESS STEEL · HARD SURFACING · TOOL STEEL

For more details, circle No. 42 on Reader Information Card

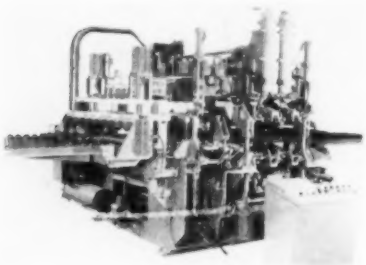
ture and air frames. It is also suitable on farms and in job shops and garages where small transformers are normally used.

For more details, circle No. 41 on Reader Information Card.

Resistance Welder

A special lap-seam resistance welder joins successive strips of aluminum alloys for continuous processing at Aluminum Company of America, Alcoa, Tenn. The welder, designed and built by the Taylor-Winfield Corp., Warren, Ohio, handles alloys such as 618, 248 and 758 from 0.010 to 0.080 in. thick, in strips as wide as 64 in.

Either plain or alclad aluminum



strip is fed into the welding machine prior to heat treating. A built-in shear square-cuts the trailing edge of one uncoiled strip and the leading edge of the following strip. Four welding wheels move across the overlapped edges, joining the two strips.

Two 250-kva transformers power the special welding machine. Mechanical transfer devices incorporated in the welder receive the strip, position it properly and move it towards the continuous heat-treating line after it is welded. The operator controls all operations from a nearby push-button control station.

For more details, circle No. 44 on Reader Information Card.

Tool-Steel Rod

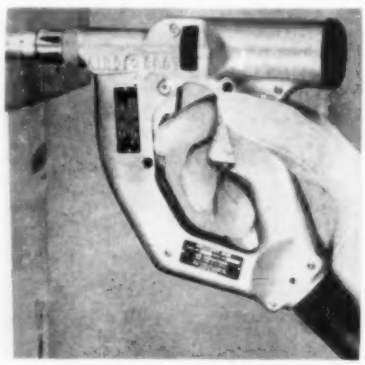
A bare tool-steel rod, Eurekaweld 1000-A, for the inert-arc and atomic-hydrogen welding of the new high-strength-alloy tool steels, has been developed by the Welding Equipment & Supply Co., 5225 East Davison Ave., Detroit, Mich.

This rod reportedly matches in special analysis and qualities the ultra high strength steels that must maintain tensile strengths of 150,000 psi at elevated temperatures of 1000° F.

For more details, circle No. 45 on Reader Information Card.

Spot Welding Accessory

The availability of an accessory unit designed for service with the Aircospot Gun in the arc-spot welding of light-gage metals is announced by Air Re-



duction Sales Co. Inc., a Division of Air Reduction Co. Inc., 150 E. 42nd St., New York 17, N. Y.

The manufacturer states that the new "crater eliminator control" functions to regulate automatically the cooling rate of Aircospot welds. With this unit, the arc does not end abruptly when the trigger is released and welding action stops; instead, its intensity drops to a lower lever before it extinguishes. Consequently, the weld cools more slowly, which minimizes or eliminates the tendency toward weld cracking in certain metals when they cool rapidly. This postheating of the weld reportedly produces a smooth, craterless spot of good appearance. Post-weld current intensity and post-weld heat time are adjustable as required by material thickness and other variables.

As a result of eighteen months of development work and field trial, the Aircospot gun has been modified by the installation of a new spatter trap which prevents particles of molten metal from entering the nozzle; a weld-quality control feature, an adjustable trigger stop, has been incorporated; and various changes have been made in the control panel.

For more details, circle No. 46 on Reader Information Card.

Anode

A radiation-cooled, high-power industrial triode, Type 7092, was announced by Amperex Electronic Corp., 230 Duffy Ave., Hicksville, L. I. N. Y.

The new internal anode is designed for industrial oscillator applications in ultrasonic, induction or dielectric heating equipment.

The manufacturer discloses that the heavy-duty anode is able to withstand heavy overloads. The tube envelope is constructed of extra-thick, hard glass for temperature resistance and ruggedness.

Used in continuous class C operation, 2 kw power in industrial loads can be obtained, and 3 kw in intermittent operation. The thoriated-tungsten filament of the type 7092 is rated at 6.3 v, 32.5 amp.

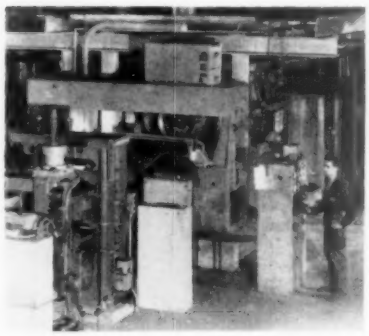
For more details, circle No. 47 on Reader Information Card.

Seam Welder

A resistance seam welder, installed recently by the Taylor-Winfield Corp., Warren, Ohio, in a Canadian continuous-annealing line, welds strip steel up to 48 in. wide.

According to the manufacturer, the weld is made at a rate of from 24 to 72 fpm.

Dominion Foundries and Steel, Ltd., Hamilton, Ontario, processes the low-carbon steel coils through welding,



cleaning and annealing operations in the continuously moving line. The strip ranges from 0.0067 to 0.035 in. thick.

The welder is a travel-head seam type that welds an overlap joint between succeeding coils. A special high-speed drive makes the weld quickly, while a reserve loop in the strip is being processed, permitting continuous line operation.

The welding machine has provisions for welding in opposite directions. A shear built into the welder shears the strip ends to obtain a high-quality seam. The welding transformer is 50 kva, 550 v, 60 cycle.

Designed and built by Aetna-Standard Engineering Co., Pittsburgh, Pa., the "Dofasco" line also converts to a cleaning line. The annealing furnace can be by-passed without interfering with other processing operations.

For more details, circle No. 48 on Reader Information Card.

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NEW LITERATURE

Copper Welding Rod Specification Issued by Joint AWS-ASTM Committees

The 2nd edition of "Copper and Copper-Alloy Welding Rods," a specification prepared by the joint committees of the AMERICAN WELDING SOCIETY and the ASTM, is available for distribution. The eleven classifications in this specification (AWS A5.10) include copper, copper-silicon, copper-tin, copper-nickel, copper-zinc and copper-aluminum welding rods. They are for use with the oxyacetylene, carbon-arc and gas tungsten-arc welding processes. Chemical composition, mechanical properties and usability characteristics of each classification are given together with tests which verify these properties.

Several changes have made the revised edition more timely. Two specifications, one for manganese-bronze (RCuZn-B) and another for aluminum-bronze (RCuAl-A2), have been eliminated due to their lack of significance in the field. Two copper-zinc welding rods (RBCuZn-A and RBCuZn-D), in addition to their inclusion in this particular specification, have been incorporated in the "Brazing Filler Metal" specification (AWS A 5.8). A new low-fuming bronze alloy has replaced the one termed obsolete.

An appendix is included as a guide for the user in selecting the proper welding rod for efficient use. Information is also provided for each filler metal for joining different base metals by the various welding methods.

Copies may be obtained at 40 cents from the AMERICAN WELDING SOCIETY, 33 W. 39th St., New York 18, N. Y.

Arc Welding Guide

"How to Get Better Welds," a revised edition of "Welders' Vest Pocket Guide" contains 60 pages of arc welding

information, is now available from Hobart Brothers Co., Troy, Ohio. Included in the information are metals and electrodes, 4 essentials of proper welding procedures, the fillet weld, types of joints, typical welding positions, welding symbols, standard steel shapes available for welding, causes of common welding troubles and what to do about them, definition of welding terms, weight of weld metal deposited, spark tests by grinding, factors to consider in selecting electrodes, types of electrodes, how to select welding electrodes to weld ferrous metals, how to select electrodes to weld corrosion-resisting steels, electrode identification key, explanation of AWS classification numbers and comparative index of welding electrodes.

For your free copy, circle No. 50 on Reader Information Card.

Electric Welding Outfit

A 4-page pamphlet entitled "Lincwelder 100" is now available from the Lincoln Electric Co., Cleveland 17, Ohio.

The manufacturer states that the Lincwelder 100 power source and accessory kit can combine such operations as welding, cutting, soldering, brazing and heating. The unit is a reportedly useful addition to "build-it-yourself" enthusiasts, contractors and manufacturers. The power source operates with an input power of 208/230 v, single phase, 60 cycles. Rating at 25 v is 100 amp with a current range of 50 to 100 amp. The kit includes "Selfweld" electrodes, soldering carbons and adapter, "Selfweld" holder, cables and handshield with lens. An arc torch for heating, soldering and brazing is available as optional equipment.

For your free copy, circle No. 51 on Reader Information Card.

Hard-Surfacing News

Volume 2, No. 5 of "Colmonoy Alloy News," published by Wall Colmonoy Corp., 19345 John R St., Detroit 3, Mich., is available for distribution.

Articles appearing in this 4-page pamphlet concern the hard surfacing of spur gears in ball mills, stem tubes in refinery catalyst units and bed knives in paper mills. Brazing operations on gas-pipe assemblies are also discussed. A new product of the company, Colmonoy No. 56, is described, and one of its applications, the surfacing of extrusion screws in the plastics industry, is illustrated.

For your free copy, circle No. 52 on Reader Information Card.

Welding Data Book

The 1958 edition of the 180-page pocket-sized welding data book (TIS 2575A) is now available from Eutectic Welding Alloys Corp., Flushing 58, N. Y. The book covers 120 welding rods, electrodes and welding compounds.

According to the manufacturer, the welding data book is a guide to improved torch and metallic-arc welding, brazing and soldering. Information is given for fabrication, maintenance repair and salvage, overlaying for wear and corrosion resistance and welding of dirty, rusted parts. Special welding applications such as joints with high electrical conductivity, resistance to chemicals, tinning and plating are covered. Data is also given on methods of gouging, chamfering and removing of unwanted metal without special equipment.

Weld preparation steps are reportedly given for all metals. The welding procedures presented stress ways to save dismantling, pre- and postheating. Procedures given also discuss maximum machinability, color matching, weld strengths and reductions of amount of alloy used, finishing time and work.

For your free copy, circle No. 53 on Reader Information Card.

Hard Surfacing

The Stoody Co., Whittier, Calif., has recently published the summer 1957 issue of "Fusion Facts," Vol. 17, No. 3. Articles in the 22-page booklet include various hard-surfacing processes used in such industries as rock products, cement, farming and brick and clay. A new hard-surfacing electrode is discussed. The manufacturer recommends this all-position electrode, known as Stoody 1030, for certain applications where wear resistance is required. The illustrated booklet emphasizes the semiautomatic and manual methods of hard surfacing.

For your free copy, circle No. 54 on Reader Information Card.

Nondestructive Testing

The Fall 1957 issue, Vol. 5, No. 1, of "Magnafacts" has been issued by Magnaflux Corp., 7300 W. Lawrence Ave., Chicago, Ill. Included in the 12-page brochure are such articles that describe applications of nondestructive testing on helicopters used in the petroleum industry, sector shafts in automobiles, maintenance and production facilities in a cement plant and the hull of a tugboat.

For your free copy, circle No. 55 on Reader Information Card.

Isotopes and Stainless Steel

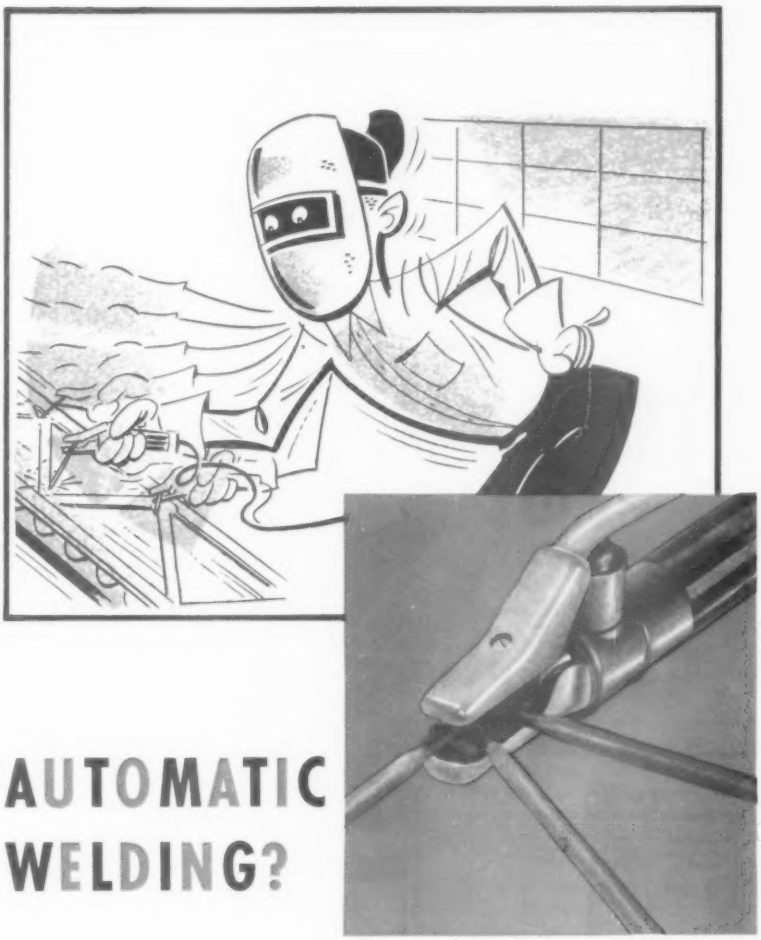
"Foote Prints," a technical booklet published by Foote Mineral Co., 18 W. Chelten Ave., Philadelphia 44, Pa., is available from the manufacturer. Vol. 29, No. 1 of this 32-page publication includes an article entitled "The Short-Lived Radioactive Isotopes" by Dr. Milton A. Rothman of Bartol Research Foundation. Another article, "What Are Stainless Steels?" by Joseph Winlock, retired chief metallurgist of the Budd Co., is of primary interest to engineers and technicians with no formal metallurgical training.

For your free copy, circle No. 56 on Reader Information Card.

Spot Welding

The September 1957 issue of "Tips and Dies," Vol. 3, No. 2, is available from the Federal Machine and Welder Co., Warren, Ohio. In color, the 4-page pamphlet describes some of the recent spot-welding operations used on the fuselages of the Boeing KC-135 jet, tanker transports and the "707" commercial jet Stratoliners. Federal's mechanical press equipment, known as "Warco," is also described.

For your free copy, circle No. 57 on Reader Information Card.



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Aluminum cranes are now being welded using semiautomatic equipment.

New Alcoa welding alloy makes possible the aluminum crane

For a long time, the idea of an aluminum crane has interested designers. Much lighter in weight, it would permit lower cost building foundations or a higher capacity crane on the same foundations. But how to make it? Riveted construction is outmoded and expensive.

Now aluminum cranes are being built, thanks to a new Alcoa alloy. Designated 5456, this new alloy has the highest as-welded strength of any commercial aluminum alloy yet developed. Guaranteed minimum properties are 42,000 psi ultimate and 19,000 psi yield on the plate and equally good ultimate strength across the weld.

Using the new alloy and the inert-gas consumable-electrode process, it costs no more to fabricate aluminum cranes than steel cranes. There are long welding runs involved, up to 60 feet, and semiautomatic equipment is used. Speeds as high as 80" per minute are achieved.

In addition to their light weight, these aluminum cranes can be used in corrosive atmospheres and will require no painting.

Alcoa is headquarters for fresh and exciting ideas like this on how to weld, braze or solder aluminum. Get in touch with an Alcoa distributor listed at right. And write now for booklets and films that show how easy it is to weld, braze and solder aluminum. Aluminum Company of America, 1711-M Alcoa Building, Pittsburgh 19, Pa.

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Surfacing

"Haynes Hard-Facing Alloys—Bare Rods, Powder, Crushed Particles" is now available from Haynes Stellite Co., Division of Union Carbide Corp., 30 E. 42nd St., New York 17, N. Y. This 8-page booklet describes the chemical composition, some properties, typical applications and application procedures for 11 Haynes alloys that are available as bare rods, crushed particles and powder. These include four iron-base alloys, three cobalt-base alloys, Haystellite cast tungsten carbide and three nickel-base alloys.

For your free copy, circle No. 60 on Reader Information Card.

Titanium Wire and Rod

A reference work, "Conversion Table for TitaniumWire and Rod," has been published by Johnston & Funk Titanium Corp., W. Kemrow Ave., Wooster, Ohio. The tables convert titanium wire-diameter sizes (0.002 to 0.200) to lineal ft per lb and titanium round and square bar stock ($^1/_{16}$ to $^3/_4$ in.) to lb per lineal ft.

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Metallizing and Repairs

The Protective Coatings Division of Metalweld, Inc., Scotts Lane & Abbotsford Rd., Philadelphia, has just published two new bulletins describing its services to industry.

The first bulletin deals with metallizing which is the process of spraying molten metals onto a base surface to build up worn mechanical equipment, to apply hard wearing surfaces, to correct surface defects and to restore dimensions. By this method, according to Metalweld, old parts can be salvaged, mis-machined parts and castings reclaimed, outside diameters increased, inside diameters increased, mechanical, chemical or electrical properties imparted.

The second bulletin covers welding repairs of structural and processing equipment as well as fabrication of the latter. The bulletin outlines the various welding processes used for making repairs to broken or worn machinery, structural repairs to railroad bridges, storage tanks, material handling equipment.

For your free copies, circle No. 62 on Reader Information Card.

Resistance Welding

Number 579 of "Weld-It," a 4-page pamphlet from the Taylor-Winfield Corp., Warren, Ohio, is now available to readers.

The feature article describes seam welding operations in fabricating skin surfaces of the rocket-powered North American X-15 research airplane. A second article depicts various flash welding uses at Dresser Manufacturing in the fabrication of circular flash-butt weldments.

For your free copy, circle No. 63 on Reader Information Card.

Metallizing

The Metallizing Engineering Co., Inc., 1101 Prospect Ave., Westbury, L. I., N. Y., are offering an 8-page booklet entitled "Metallizing Unlimited." Various applications, in which life expectancies of machine parts can reportedly be increased 3 to 4 times over the life of the original base metals, are discussed.

For your free copy, circle No. 64 on Reader Information Card.

Grinding

"Tool Room Grinding of Alloy, High-Speed, and Die Steels," a 24-page brochure, is now available from the Bonded Abrasives Division of the Carborundum Co., Niagara Falls, N. Y.

Designed to be a single source book on grinding for tool room men, it covers 22 areas in the field with short, factual copy, illustrative pictures and clarifying charts.

The brochure treats the following areas: aluminum-oxide abrasives; properties and uses; wheel shapes and markings; broaches, chasers, cutters, circular form tools and hobs; offhand grinding; tap sharpening; tool post grinders; drill sharpening; cutoff and slotting; cylindrical grinding; surface grinding; mounted wheels; die grinding and barbering; and sticks, stones and finishing compounds.

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Automatic Surfacing

Preventive and operational maintenance of crawler type tractor parts are featured in a new 6-page brochure entitled, "Rebuild Worn Crawler Type Tractor Parts The Rexare Automatic Way," Rexare Form No. 757, available from the Sight Feed Generator Co., West Alexandria, Ohio.

The different stages and conditions of wear patterns of tractor parts are illustrated together with a composite of the tractor parts that can be rebuilt automatically such as rollers, flanges, idlers, rails, grouser bars and pads. It is claimed by the manufacturer that Rexare corrects the wear pattern, restores the original efficiency and increases the wear resistance at considerable savings.

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SUPPLEMENT TO THE WELDING JOURNAL, DECEMBER, 1957

X-RAY DIFFRACTION FOR RESIDUAL STRESS MEASUREMENTS OF RESTRAINED WELDMENTS

Theoretical and experimental studies indicate that the use of X-ray diffraction by the two-exposure method is an excellent tool for the measurement of residual stresses in welded Monel

BY E. H. KINELSKI AND J. A. BERGER

ABSTRACT. The theoretical and practical aspects of determining residual stresses by means of X-ray diffraction are presented. This method was used for determining the stresses in Monel plate weldments prepared by means of the metal-arc, gas-shielded tungsten-arc, and gas-shielded consumable-electrode welding processes. The residual-stress patterns in the weldments are compared for two conditions of preheat and interbead temperatures—room temperature and 300° F. The results indicate that the 300° F preheat and interbeard temperature has a beneficial effect upon reducing the stress gradient for the consumable-electrode welds, only. The X-ray diffraction method of measuring residual stresses in welds was found to be an excellent "tool" for the study of welding variables and problems.

Introduction

In the last quarter of a century, the use of X-rays as a quantitative analytical tool for the measurement of crystal structure, chemical composition and residual stress has been increasing phenomenally. In spite of the rapidly increasing usefulness of the method of measuring residual stresses by means of X-ray diffraction techniques, its use in the welding-metallurgy field has been very meager.[1,2] Although the theory and application of the X-ray method are complex, it is believed that more use would be made of the "tool" if welding-research personnel were aware of its potential applications.

A simple, butt-welded specimen was chosen to illustrate the usefulness of the X-ray diffraction method of measuring residual stresses resulting from welding under restraint. Three commonly used methods of welding were employed:

1. Metallic arc using a flux-coated electrode.
2. Gas-shielded, tungsten-arc using a bare filler wire.
3. Gas-shielded, consumable-electrode using a bare filler wire.

Although the alloy used (Monel-nickel-copper alloy) for the welding tests in this investigation does not require a preheat or the maintenance of a high interbead temperature, a large number of complex alloy systems would require such treatment where high stresses are anticipated. Therefore, the welds were made first with no preheat and an interbead temperature of 100° F and second with a 300° F preheat and an interbead temperature of 300° F.

The resulting stress data were analyzed graphically and compared with the anticipated behavior of the welding processes with their variable heat inputs. It is hoped that the data and experimentation using commonly experienced welding variables will encourage others to tackle similar or even more difficult problems in residual stresses associated with welding.

Theory of X-ray Diffraction

Although a major emphasis will be placed upon the residual stress measurements in Monel weldments, a brief description will be presented of the theory of X-ray diffraction and how it is used for stress determinations.

When monochromatic X-radiation impinges upon atoms in a metallic crystal, the waves are scattered by the electrons of the atomic structure, and superposition of the waves results in diffraction.[3] By the use of Bragg's Law, the condition for reinforcement of all of the reflected rays is:

$$n\lambda = 2d \sin \theta \qquad (1)$$

n = whole numbers.
λ = wave length.
d = atom-plane spacing.
θ = angle of incidence and reflection.

The X-ray diffraction method of stress analysis actually measures the strain existing in the specimen by measuring the change in the interatomic distance between planes of atoms. By applying Hooke's Law to a three-dimensional stress-strain problem,[4] an equation is developed which relates the elastic stress in one direction in the surface, Σ, to the change in d spacings, $d_\perp - d_\psi$:

$$\Sigma = \frac{-(d_\perp - d_\psi)E}{d_\perp (1 + N) \sin^2 \psi} \qquad (2)$$

E. H. Kinelski is associated with the International Nickel Co., Inc., Research Laboratory, Bayonne, N. J. and graduate student at University of Pittsburgh. J. A. Berger is Professor and Head, Department of Metallurgical Engineering, University of Pittsburgh School of Mines, Pittsburgh, Pa.

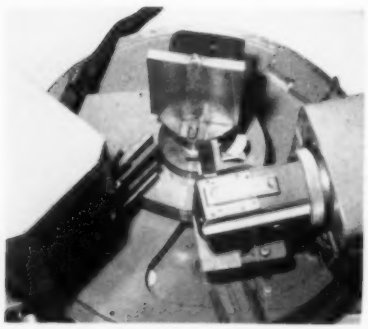

Fig. 1 Position of weldment on stage of X-ray spectrometer

where

E = Young's Modulus of Elasticity.
N = Poisson's ratio.
ψ = 45°.
$d_\perp$ = interatomic spacing when X-ray beam is perpendicular to the surface.
d_ψ = interatomic spacing when X-ray beam is oblique (45°) to the surface.

In order to measure Σ, one cannot measure the change in d spacing directly. However, the Bragg angle, θ, can be measured by X-ray diffraction, and Mihalisin[5] has shown how Σ can be related to the change in Bragg angle with the following equation:

$$\Sigma = \frac{(\theta_\perp - \theta_\psi)\, E}{\tan\theta\,(1 + N)\sin^2\psi} \quad (3)$$

Therefore, the determination of stresses in the surface of a specimen can be made by determining the Bragg angle for two conditions of X-ray diffraction, one where the X-ray beam is normal to the surface and the other at 45° to the surface.

Determination of $(\theta_\perp - \theta_\psi)$ by X-ray Diffraction

The welded specimens were placed on a special stage of a General Electric, XRD-3, X-ray spectrometer as illustrated in Fig. 1. The relative positions of the weldment, X-ray tube and proportional counter on the spectrogoniometer are illustrated in Fig. 2. In the normal position of irradiation with X-rays, the planes of atoms, (420) for Monel, whose interatomic distance is being measured, are parallel to the surface of the metal. In the oblique position, the planes are at 45° to the surface. If there is no change in the Bragg angle, θ, between the normal and the oblique irradiation, then no stress exists on the surface of the metal in the plane of measurement. If the Bragg angle in the normal irradiation is larger than in the oblique, then the stresses are tensile, or the atomic spacing is expanded. If the oblique irradiation is the largest, then the stresses are compressive, or the atomic spacing is contracted.

For each stress measurement, a series of measurements of X-ray intensity (counts per 40 sec are generated by the proportional counter when actuated by the diffracted X-rays and measured by means of a Scaler) are made at various positions of Bragg angle, θ, on the goniometer protractor. (The protractor actually is calibrated in terms of 2θ; however, the calculations of stress are made based on θ.) By plotting X-ray intensity vs. 2θ as in Fig. 3, the maximum points of the curves are used as the values of 2θ for the normal and oblique irradiations. The values are then used in eq 3 to determine the stress. If many calculations are to be determined, then

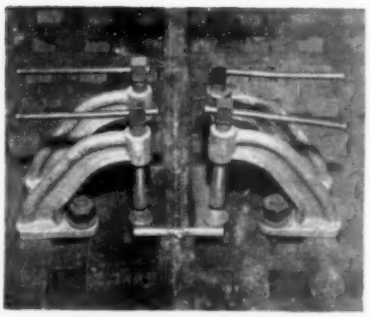

Fig. 4 Position of weldment on hold-down table during welding

eq 3 may be re-written as

$$\Sigma = (\theta_\perp - \theta_\psi)\frac{E}{\tan\theta\,(1 + N)\sin^2\psi} \quad (4)$$

$$\Sigma = (\theta_\perp - \theta_\psi)\,k$$

"k" for Monel, which has been subjected to X-ray diffraction using a copper target X-ray tube, is equal to 856 lb per sq in. per 0.01°.

Sample Stress Analysis of a Monel Plate Welded Under Variable Conditions of Heat Input

In order to illustrate the practical aspects of the X-ray diffraction method of stress measurement, an actual stress problem was used to indicate its usefulness in the field of welding. Since the choice of a metal determines the ease or difficulty with which X-ray diffraction measurements are made, a nickel alloy, Monel, was chosen which gave sharp X-ray diffraction peaks. Monel has an approximate composition of 65% nickel and 35% copper with iron and manganese also present. It forms a continuous solid solution and possesses a face-centered cubic structure.

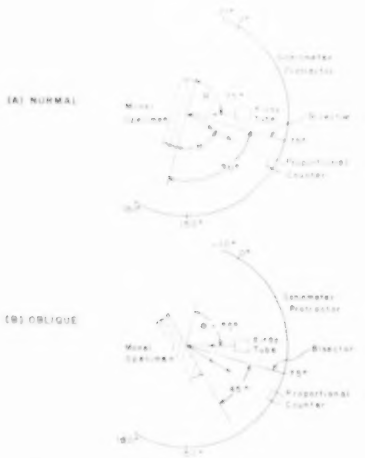

Fig. 2 Relative positions of specimen, X-ray tube, and proportional counter on spectrogoniometer

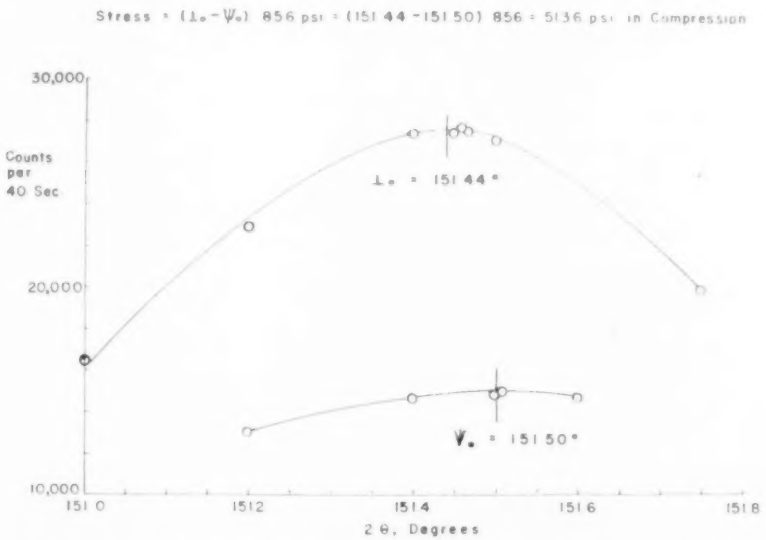

Fig. 3 X-ray intensity vs. 2θ for base metal of weldment 5620, test no. 14

Table 1—Welding Conditions for Monel Plate Weldments

Weld no.	*Welding process*	*Welding electrode or wire*	*Diameter size electrode*	*No. of beads*	*Preheat*	*Interbead temperature, °F*	*Gas flow*	*Welding speed*	*Amperage*
5619	Metal-arc	AWS-E3N10 Monel flux-coated	5/32 in.	4	None	100	...	...	145
5620	Metal-arc	AWS-E3N10 Monel flux-coated	5/32 in.	4	300° F	300	...	...	145
5631	Metal-arc	AWS-E3N10 Monel flux-coated	5/32 in.	4	None	100	...	...	145
5621	Tungsten-arc	AWS-ERN 60 Monel wire	1/8 in.	5	None	100	20 cfh argon	...	225
5622	Tungsten-arc	AWS-ERN 60 Monel wire	1/8 in.	5	300° F	300	20 cfh argon	...	225
5624	Consumable-electrode	AWS-ERN 60 Monel wire	1/16 in.	3	None	100	50 cfh argon	170 ipm	310
5625	Consumable-electrode	AWS-ERN 60 Monel wire	1/16 in.	3	300° F	300	50 cfh argon	170 ipm	310

It was also chosen because it is relatively easy to form crack-free welds in Monel using the three welding methods under consideration for this experimentation. In a more complex alloy, the interpretation of the residual stresses might be rendered difficult by the formation of cracks since an unknown amount of stress relief would occur as a result of the cracking.

In welding a heavy plate of metal, such as Monel, three welding methods might be employed, namely:

(*a*) Metal-arc using a flux-coated electrode.

(*b*) Gas-shielded, tungsten-arc using a bare wire.

(*c*) Gas-shielded, consumable-electrode using a bare wire.

These three methods were used for the weldments under test. Since a weldment produced in production would be subjected to restraint during welding, the test specimens produced for this study were clamped to a heavy welding table as in Fig. 4 to induce the same type of severe restraint in all test specimens. At the conclusion of welding and after cooling to room temperature, all of the plates were flat on the table. It was desirable to subject the specimens to two conditions of restraint (or stress relief) by means of the control of the preheat and the interbead temperature during welding. In one condition, the weldment was not preheated and a 100° F interbead temperature was maintained. In the second condition, a 300° F preheat was used, and the interbead temperature was controlled at 300° F. The following sections of the paper describe the experimentation and the interesting data which resulted from it.

Test Procedure

The 1/2-in. thick Monel plate, heat M 5778 B, had the following mill chemical analysis: C 0.14, Fe 1.39, Si 0.20, Ni 66.19, Mn 0.95, S 0.006, Cu 31.10. The plate was obtained in the hot rolled, annealed and pickled condition and machined as follows: 1/2-in. thick x 2 1/4-in. wide x 5-in. long, 40° bevel with a lip of 3/32 in. An especially diligent attempt was made to machine the test pieces as accurately as possible in order to eliminate any variation in residual stresses as a result of differences in size between base plates.

The plates were held down on a large hold-down welding table by means of four clamps during welding (Fig. 4) to impose restraint upon the weldment. Each weld was completed flush with the top of the Monel plate in order to minimize any variables resulting from weld reinforcement.

The welding conditions are given in Table 1. The Monel plates were preheated by means of an oxyacetylene welding torch, and the temperature was measured with an Alnor "Pyrocon" contact pyrometer. After the restrained welds had cooled to room temperature, no significant movement of the weldment had occurred away from the hold-down table.

Since it was intended to determine the residual stresses while the weldments were positioned on edge with the crater end at the bottom (as in Fig. 1), it was necessary to machine the crater end slightly to create a flat edge perpendicular to the length of the weld bead. Using the stand available

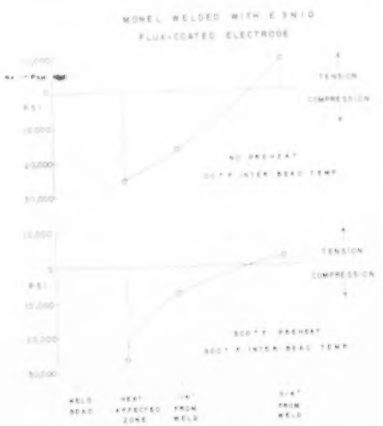

Fig. 5 X-ray diffraction stress data

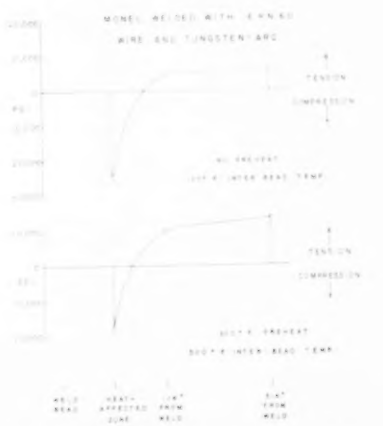

Fig. 6 X-ray diffraction stress data

Fig. 7 X-ray diffraction stress data

at the International Nickel Co. for stress measurements by means of X-rays, the beam impinged upon the weldment at a position $1^1/_8$ in. from the bottom of the welded plate. In other words, the stresses being measured were those transverse to the weld at a position $1^1/_8$ in. from the crater end and lying in the top surface of the weldment.

Test Results

The residual stresses induced by welding were determined in the following positions in a transverse direction to the Monel plate welds:

1. Weld bead.
2. Heat-affected zone with the outline of the X-ray beam on the edge of the weld bead.
3. Parent or base metal with the beam positioned $^1/_4$ in. from the edge of the weld.
4. Base metal with the beam positioned 1 in. from the edge of the plate or approximately $^3/_4$ in. from the edge of the weld bead.

The stress results are given in Figs. 5, 6 and 7.

In determining the stress pattern for the weldments, it was necessary to know the residual stresses in the hot rolled, annealed and pickled Monel plate before welding. The unwelded plate had an internal residual stress of 6590 psi, in compression, which probably resulted from a straightening pass through a cold mill after the annealing treatment. In determining the stresses in Figs. 5, 6 and 7, the residual stresses in the unwelded plate were subtracted algebraically from the total residual stresses obtained for each weldment position.

In general, it was impossible to determine the change in θ for the weld beads with their wavy surface patterns, because no sharp peaks of X-ray intensity versus 2θ were obtained. However, the data on the plate adjacent to the weld were believed to be of great value.

As a check on the reproducibility of the X-ray diffraction method for determining stresses in weldments, a repeat of the tests was made on a weldment produced by the metal-arc process with no preheat and a 100° F interbead temperature. The test results were compared as follows:

Location	*Original W 5619*	*Compression or tension*	*Repeat W 5631*	*Compression or tension*	*Difference*
Weld bead	30,000 psi	Compression	17,000 psi	Compression	False data
Heat-affected zone	28,200 psi	Compression	32,500 psi	Compression	4300 psi
$^1/_4$ in. from weld	Not measured		23,100 psi	Compression	
$^3/_4$ in. from weld	3080 psi	Compression	2580 psi	Tension	7660 psi

Therefore, for two weldments prepared under identical conditions except for the fact that they were welded weeks apart, the stress pattern was quite reproducible—within 5000 psi—at the heat-affected zone and the base metal $^3/_4$ in. from the weld. The weld-bead data were believed to be erroneous, because of the uncertainty of determining the peaks from the X-radiation versus 2θ plotted curves.

In order to illustrate the stress patterns in these weldments, three graphs were prepared to illustrate the residual stresses versus their location on the weldments. The residual-stress values were corrected by subtracting algebraically the stress obtained in the unwelded plate—6590 psi in compression—from all of the stress values obtained on weldments. These corrected stress plots, Figs. 5, 6 and 7, will be discussed in the next section of this paper.

Discussion of Test Results

The culmination of all of the test data was presented as graphs of the residual stresses vs. their location on the weldment (Fig. 5, 6 and 7). In analyzing the data presented graphically, it was apparent that the patterns of residual stresses due to welding were complicated. However, a few important generalizations were deduced with some confidence when the data were considered as two distinct observations.

The first observation was that the maximum stress reached in the heat-affected zone of all of the weldments was an important consideration and could be compared. For example, preheating to 300° F and maintaining an interbead temperature of 300° F reduced the maximum stress in the heat-affected zone of the tungsten-arc welds (Fig. 6) from 24,200 to 17,400 psi.

The second observation was that the change in stress between the heat-affected zone and the base metal $^1/_4$ in. away from the weld was an important consideration. For example, the change in stress between these two locations in the consumable-electrode welds (Fig. 7) when preheat was used, effected a reduction from 41,100 to 22,200 psi.

The following table is a summary of the results of the plotted data:

	Flux-coated, metal-arc	*Tungsten-arc*	*Consumable-electrode*
Maximum compressive stresses reached in heat-affected zones			
No preheat, 100° F IBT	25,910	24,210	18,210
300° F Preheat & IBT	26,810	17,410	21,610
Change in stress between heat-affected zone and position $^1/_4$ in. away			
No preheat, 100° F IBT	9,400	29,090	41,100
300° F Preheat & IBT	18,850	27,420	22,200

Referring to the table above, a decrease in the residual-stress level reached in the heat-affected zone was obtained by preheating the tungsten-arc weldments only. The other two methods caused no appreciable change in residual stress in the heat-affected zone when preheat and a 300° F interbead temperature was maintained. Preheating effected a marked decrease in the difference in stress between the heat-affected zone and a position $^1/_4$ in. away in consumable-electrode welds, had no influence on the tungsten-arc welds, and had the reverse effect on the flux-coated metal-arc welds.

Summarizing the effects of preheating from all the observations, it appears that an advantage is to be obtained by preheating the consumable-electrode welds, whereas no advantage is to be gained for the tungsten-arc or metal-arc welds in Monel. However, it must be recognized that the extent of the heated area of a weld can vary for each welding process by changing the welding speeds and amperages. Therefore, different patterns of residual stresses could have been obtained from those discerned in this investigation by varying the energy inputs.

In discussing the results of the residual stress determinations, an explanation appears necessary for the existence of compressive residual stresses adjacent to the weld bead. Although Barrett[6] mentions a number of theoretical reasons for the existence of compressive stresses, a practical explanation can be presented by considering the manner in which the weldments would have been deformed if the plates were not clamped securely to a hold-down table during welding. If the weldments were free to move during welding, the edges of the plates would bow upward. How-

ever, when the plates were held down, the bow would not occur, and the surface stresses would be tensile *applied* stresses. Upon cooling of the welds, the weldments remained flat. Therefore, the *residual* stresses present in the weldment must have been in compression to overcome or "buck" the tensile applied stresses.

Another method of interpreting the stress values adjacent to the weld would be to consider the actual expansion or contraction of the atom planes. In the welded specimen investigated, the X-ray beam impinged upon the specimen as follows:

Normal beam

If d_0 is the distance between the planes being measured with no strain present, then $d_\perp$ is less than d_0 when the strain was obtained from a tensile applied load.

Oblique Beam

$d_\angle$ is greater than d_0 when a tensile-applied load is imposed on the weldment.

Therefore, since $(d_\perp - d_\angle)$ results in a negative value, the lattice is contracted, and the calculated residual stresses are in compression. (A simple analogy would be the stretching of a rubber band.) The same reasoning can be used when the applied loads act in compression on the specimen.

It also may be questioned that the stresses measured by X-ray diffraction are not related directly to the welding stresses. Barrett[6] and Alexander and Klug[7] cite examples of stress measurements in specimens that have been deformed by elasticity and plasticity. If a strain-free metal is stressed within its elastic limits, the lattice strains disappear when the stress is removed. However, if a metal is plastically deformed, a residual lattice strain remains after the stress is removed. In the case of the restrained welds in Monel, it is believed that at the temperatures involved in welding, almost all of the deformation taking place is in the plastic region. Therefore, it is logical to assume that the measurement of the residual stresses (after cooling) is at least proportional to the welding stresses if not a direct measure of the welding stresses. It is this belief which appears to justify a greater amount of stress measurements by means of X-ray diffraction in the welding industry. To repeat briefly the benefits and disadvantages of this method of measuring stresses, they may be summarized as follows:

Advantages of the X-ray diffraction method:

(*a*) It is a nondestructive method. By use of the two-exposure method of X-ray diffraction, there is also no need for taking measurements of the material in the completely unstressed condition to establish a base line for the metal crystal structure.

(*b*) It is the only method for measuring residual stresses nondestructively.

(*c*) It measures a very small area of strain and allows a means for measuring steep gradients, as in welding.

Disadvantages of the X-ray diffraction method:

(*a*) The grain size of the metal must be neither too small (as in hardened steel) nor too large.

(*b*) Only surface stresses can be measured.

(*c*) Costly equipment is required.

(*d*) The surface must be smooth.

Conclusions

Theoretically and experimentally, the use of X-ray diffraction by the two-exposure method has been demonstrated to provide an excellent tool for the measurement of residual stresses in welded Monel. Although the stresses could not be measured in the weld bead because of the rough surface, a useful stress-distribution pattern was obtained by measuring the stresses in the heat-affected zone and in the base metal. In Monel weldments where the preheat and interbead temperatures were controlled at room temperature and 300° F, the latter temperature provided a beneficial stress relief in the consumable-electrode welds. No benefit of a high-temperature preheat or interbead temperature was obtained on tungsten-arc welds or metal-arc welds on Monel.

Acknowledgments

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References

1. Norton, J. T., and Loring, B. M., "Stress Measurements in Weldments by X-Rays," THE WELDING JOURNAL **20**, 284-s to 287-s (1941).
2. Norton, J. T., and Rosenthal, D., "An Investigation of the Behavior of Residual Stresses Under External Load and Their Effect on Safety," *Ibid.* **22**, 63-s to 78-s (1943).
3. Barrett, C. S., "Structure of Metals," McGraw-Hill Book Co., Inc., New York, pp. 45-87 (1952).
4. Klug, H. P., and Alexander, L. E., "X-Ray Diffraction Procedures," John Wiley & Sons, New York, pp. 58-110 (1954).
5. Mihalisin, J. R., "A Study of X-Ray Stress Measurement Techniques," Partial Fulfillment of Doctor of Science, MIT, 1953.
6. Barrett, C. S., "Structure of Metals," McGraw-Hill Book Co., Inc., pp. 334-335 (1952).
7. Klug, H. P., and Alexander, L. E., "X-Ray Diffraction Procedures," John Wiley & Sons, Inc., New York, pp. 554-555 (1954).

EXPERIMENTAL WELDING WITH THE CONE ARC

Study of cone-arc welding process indicates that this can be a useful method of producing uniform tube-to-header joints if even heat-transfer conditions are maintained

BY R. E. MONROE AND D. C. MARTIN

ABSTRACT. Many of the electrical characteristics of the cone-arc welding process were studied during a program to develop welded molybdenum heat exchangers containing tube-to-header joints. Attempts to eliminate weld irregularities which appeared to be characteristic of the cone arc prompted these studies. Electrode size and shape, electrode centering, type of power source, power-source characteristics and weld circuitry were not found to be associated with the weld irregularities. Further tests showed that the production of uniform welds was primarily a function of even heat transfer around the weld periphery. High-speed motion-picture studies of the arc failed to substantiate the basic cone-arc theory of a rotating ion beam. A modified theory is presented to explain the cone-arc process.

Introduction

The cone-arc welding process was originally conceived for use in welding tube-to-header joints in small heat exchangers. Such heat exchangers are becoming increasingly important in economically extracting heat energy from highly corrosive fluids such as liquid metals. In some cases, these heat exchangers are designed for operation in limited space. This requires the welding of many small-diameter tubes into header sheets with very little spacing between the tubes. The conventional method of progressively welding the circumferences of such joints could be used, but would create uneven stress distribution surrounding the tube-to-header joint. In addition, the heat cycles of preceding welds might influence the welding conditions of a given weld. Since uniformity of these heat exchangers is a desirable property, another means of completing the welding of the heat exchangers was sought.

In 1951, Bettis and Mann,[1] of the Oak Ridge National Laboratory (ORNL) proposed a welding method based on deflecting the ion beam of an inert-gas-shielded welding arc. Patriarca and Slaughter,[2] also of ORNL, provided the name of cone arc to the welding process previously described by Bettis and Mann. Figure 1 shows the weld area in the cone-arc setup and the magnetic fields present around the arc. The parts to be welded consist of the header sheet and a tube which fits into a hole drilled into the sheet. The tungsten electrode is positioned directly over the center of the tube. Concentric with the electrode is a cylindrical magnet, magnetized so that the pole faces are at opposite ends of the cylinder. In the commercially available magnetic cups, a soft-iron pole piece fits below the magnet to concentrate the magnetic field. The lines of magnetic force run parallel to the electrode for a certain distance before fanning out. Inert gas for shielding the weld area is passed through the inside of the magnetic cup assembly.

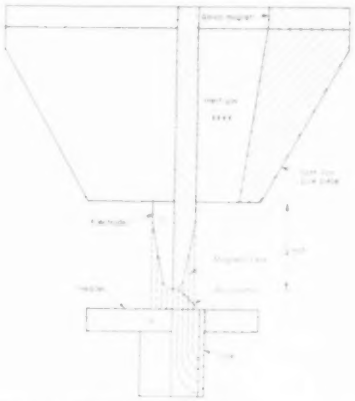

Fig. 1 Cone-arc geometry

The arc current in traveling from the electrode must establish an arc column which cuts through the magnetic field established by the magnet. Applying the elementary motor rule to the current it was theorized that the arc column would be forced to rotate around the periphery of the tube at a high speed. (It was proposed that the resulting forces caused the ion beam to rotate continuously about the periphery of the circle at a high speed with the speed being dependent on arc voltage and magnetic field strength but independent of the beam-current density.)

Experimental Work

A program to study the feasibility of producing small heat exchangers from arc-cast molybdenum was conducted using the cone-arc process. Previously, Patriarca and Slaughter[2] had used the process successfully on stainless-steel and Inconel tubes and headers. In adapting the process to molybdenum, two additional restrictions were desired. First, it was desirable to keep the welding time as short as possible to prevent excessive recrystallization and grain growth in the molybdenum heat-affected zone. Second, it was necessary that the welding be accomplished in an inert-atmosphere chamber to prevent excessive oxidation of the molybdenum parts. Molybdenum header sheets were machined from $\frac{1}{16}$-in. thick sheet. The tube size used was $\frac{5}{32}$-in. OD by 0.015-in. wall giving an inside diameter of $\frac{1}{8}$ in. The studies progressed from headers containing 5 to 19 to 52 tubes in each header sheet. A typical header containing 52 tubes welded by the cone-arc process is shown in Fig. 2. The sheet is approximately $2\frac{3}{8}$ in. square with the tubes arranged in a triangular pattern. The distance between adjacent tubes was equal to the outside diameter of the

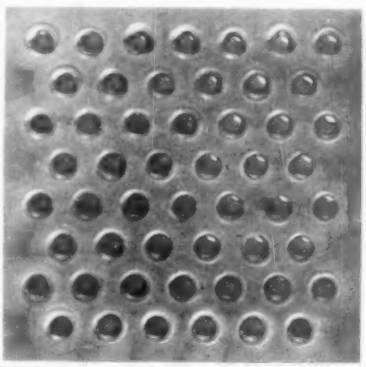

Fig. 2 Molybdenum header containing 52 tubes

R. E. Monroe is Project Engineer and D. C. Martin is Consultant, Metals Joining Division, Battelle Memorial Institute, Columbus, Ohio. Work performed under AEC Contract W-7405-eng-92.

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tubing. Close examination of this header shows the type of difficulty which prompted studies of the cone-arc welding process itself. Welds would occasionally exhibit a lack of fusion on one side of the joint or very uneven melting around the periphery, as shown. The occurrence of bad welds did not follow any logical pattern and seemed to occur at random. In attempting to pinpoint the cause of these difficulties, it was necessary to develop a better understanding of the cone-arc process.

Equipment and Procedures

First, however, it would be advisable to cover briefly the equipment and procedures used in producing weld specimens. The exact details of equipment and procedure were reported previously.[3] Either a direct-current rectifier or a balanced wave transformer could be used as the power source. The rectifier contained a built-in electronic timer. A mechanical timer was used in conjunction with the alternating-current source. These timers were connected to operate only during actual arc time. Both power sources were also equipped with high-frequency arc starters and stabilizers. Recording meters were used to obtain traces of current and voltage.

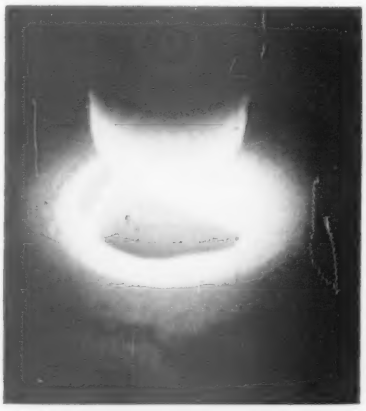
The controlled-atmosphere welding chamber used was designed to provide a high-purity atmosphere by vacuum purging at $^1/_{10}$ micron of mercury before admitting an inert-gas atmosphere. Essentially, the chamber consisted of a nickel-plated steel bell jar supported on a flat base plate. A tungsten-electrode holder with a vertical adjustment device was set on top of the bell jar. This holder was fixed with a commercially available magnetic nozzle and a zirconiated tungsten electrode. Specimens were held in a copper jig block attached to a positioning table. This table could be oriented by a control rod passing through a Wilson seal in the side of a bell jar. Three movements were available to position the specimen: rotation about the center, translation, and partial rotation pivoted at the seal. The joint was centered under the electrode by lowering the electrode into the tube before the weld. Four infrared lamps were used to preheat the specimens and jig block to the desired prewelding temperature.

Typical welding conditions are tabulated below.

Cone-Arc Welding Conditions for Molybdenum

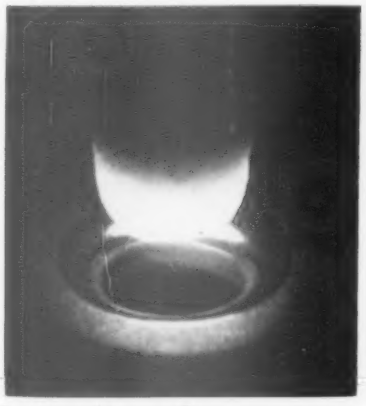
Power source	d-c rectifier
Current	200 amp
Arc voltage	18 v
Arc gap	0.040 in.
Arc time	0.5 sec.
Shielding	Grade A helium
Electrode	$^1/_8$-in. EWZr tapered to $^1/_{16}$-in. tip
Preheat	400° F

Arc ignition



Initial melting

Complete weld power on



Complete weld power off

Fig. 3 Cone-arc sequence. Frames from film taken at 3000 frames per second

Initial welding tests made in air using samples which contained a single weld joint indicated that acceptable welds could be made over a wide range of conditions. Arc time, current, the arc gap, the electrode shape, and arc angle could be changed between rather broad maximum and minimum limits with little or no effect on the shape of the resulting welds. Welds also could be made without using a magnetic cup. When testing was extended to the multitube specimens two difficulties were apparent. Some distortion of 52 tube specimens occurred, but this was minimized by selecting a welding sequence in which the outside joints were welded first. The other difficulty was the inconsistency from weld to weld mentioned previously. This inconsistency was most often manifested as an eccentric appearance of the weld produced. Studies were made of electrode positioning, size and shape, arc phenomena, type of current used, power-source characteristics and joint fit to resolve these difficulties.

Experimental Results

With the initial equipment, the exact centering of the electrode in line with the tube was not always possible. With redesigned equipment, concentricity could be maintained within 0.001 in. Although some improvement in weld quality was obtained with the improved electrode alignment, occasional bad welds still persisted.

Usually, the tungsten electrode used was the same diameter as the ID of the tubing tapered to a small diameter point. No marked differences in results could be obtained by using electrodes larger or smaller than this diameter. Bad welds could not be eliminated by changing the size or shape of the electrode.

Effects of arc phenomena are very difficult to evaluate since they depend on many other variables. In some ways, inconsistencies noticed in welding multitube headers were strongly suggestive of arc blow. One method used to correct this difficulty is to relocate the ground connection to the work. The ground connection to the copper jig block used to hold the specimens was made as uniform as possible, giving some improvement but not eliminating all the difficulties.

During the investigation of arc phenomena, high-speed motion pictures of the arc were taken at 3000 and 15,000 frames per sec. Figure 3 shows several frames taken from a film made at 3000 frames per sec. The arc column could not be observed rotating in any of

the films but appeared merely as a cone.

Since alternating current is not so susceptible to arc-blow phenomena as direct current, it was used in a number of tests. Although more uniform welds were obtained, the change in heat balance resulted in melting of the electrode tip and contamination of the weld metal. Even the use of a large-diameter electrode would not prevent electrode melting and tests with alternating current had to be discontinued.

The reliability of the direct-current power source was checked by connecting an oscilloscope to show the wave form for current and voltage. No unusual changes in the wave shape which would account for bad welds when using this equipment were noted.

The usual practice followed in assembling test specimens was to use header sheets with drilled holes which were reamed to fit the individual tubes during its assembly. This was necessary to allow for variations in the tube OD. This procedure gave an assembly in which the clearance between the tube and header sheet probably varied slightly from joint to joint. Several tests were made in which the tubes were shrunk to fit into the header sheet. Headers welded with this assembly technique were among the best produced. The same effect could be achieved also by recessing the tubes a distance equal to the tube wall thickness. This test seemed to indicate that the production of uniform welds was largely a function of obtaining uniform heat transfer around the periphery of the tube.

Analysis of Cone-Arc Theory

Observations made during the experimental program just described failed to confirm the cone-arc theory based on the concept of a rotating ion beam. In Fig. 4, the arc column itself is magnified from the tip of the electrode to the work surface and the forces which theoretically act on this column are indicated. The arc column is indicated as the line on the plane surface from the electrode to the tube periphery. Direction of the magnetic flux field is indicated by the arrows B. Both positive ion particles and negatively charged electrons are shown in the drawing. Both particles

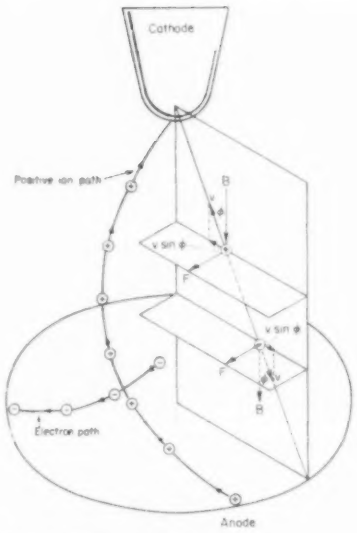


Fig. 4 Forces in the cone arc

have a velocity V at a direction which cuts through the magnetic field by the angle ϕ. The resultant of this velocity vector perpendicular to the flux field is V sine ϕ. Applying the motor rule to these particles, the resulting force which tends to rotate the particles is shown by the vector P. Since the charge and the direction of the two particles are opposite, rotational forces are exhibited in the same direction. The resulting path of a positive ion is shown by the curved line which describes somewhat of a spiral path from the work surface to the electrode under the influence of the magnetic force and the voltage gradient. A similar path exists for electron flow from the electrode to the work surface. The differences in particle movement caused by the electrode voltage gradient causes these spirals to be in opposite directions. Electrons and positive ions would be close to each other only at the point or points where their spirals cross. If we consider the acceleration of these particles in relation to their relative mass, we will find that the acceleration of the heavier positive ion particles would be much slower than the acceleration of the electron particles. Thus, we have positive ions and electrons in different paths with different accelerations. It is also known from studies of ares in vacuum that an arc column cannot be sustained without positive ions. Therefore, it does not seem possible that rotation of the arc column can occur as movement of a restricted ion beam or column.

Since welds are produced uniformly around the periphery of the tube, we must assume a conical shape for the arc column. This assumption requires that the entire tube periphery function as the anode spot. Calculation of the current density in a 200-amp arc in which the anode spot consists of the upper surface of the tube gives a value of 30,000 amp per sq in. This is about half the current density found by Jones, Kouwenhoven and Skolnik[4] in studies of anode spots of high-current arcs. If the assumption had been made that the anode spot was only half the width of the tube face, the current density would have been greater than the value proposed by these authors.

As a modification of the cone-arc theory, it is proposed that the arc column exists with a conical shape in which many positive ions and electron paths exist. The motion of these particles through the column is probably along a spiral path influenced by the external magnetic field.

Conclusions

1. The cone-arc welding process can be a useful method of producing uniform tube-to-header joints if even heat-transfer conditions are maintained.

2. A modified theory to explain the cone-arc process was developed by the application of physics laws governing the movement of charged particles.

3. The picture of the arc column as a restricted linear element does not appear to be exact for all arc configurations.

References

1. Mann, E. R., "Means for Making Uniform Circular Heliare Welds by Deflecting the Ion Beam Continuously." ANP-63 (April 9, 1951).*
2. Patriarca, P., and Slaughter, G. M. "Cone-Arc Welding." THE WELDING JOURNAL **32** (7), 597-602 (1953).
3. Monroe, R. E., and Martin, D. C., "Welding of Molybdenum Heat Exchangers." *Ibid.* **35** (12), 1222-1225 (1956).
4. Jones, T. B., Kouwenhoven, W. B., and Skolnik, M., "Heat Effects in Anode Spots of High-Current Ares." *Ibid.* **28** (10), 461-s to 466-s (1949).

* Available from Office of Technical Services, Department of Commerce.

EFFECT OF SPECIMEN GEOMETRY ON CHARPY LOW-BLOW TRANSITION TEMPERATURE

Results of investigation indicate that, within the limits of specimen size and notch types used, the low-blow transition temperature is independent of specimen geometry

BY G. M. ORNER AND C. E. HARTBOWER

ABSTRACT. An easily executed variation in the standard technique for testing Charpy impact specimens has been developed which permits a separation of the crack-initiation and crack-propagation stages of the fracture process. The technique requires initiation of a crack by means of a low-energy blow and propagation of the crack by a full-capacity blow of the impact-machine pendulum.

The definition of transition temperature is based on the concept that a brittle-fracture crack is propagated by continuous release of the elastic-stress field surrounding it, whereas a ductile fracture requires plastic-deformation work to extend the crack. When either lateral expansion or energy associated with crack propagation is plotted against testing temperature, there is an abrupt change of slope in the low-temperature region of the transition curve indicating a sudden arrest in the rate of decrease of work required for crack propagation. The resulting inflection point is believed to occur at the temperature at which the plastic-deformation work required to propagate the crack in the center portion of the test specimen away from the free surfaces is zero; the plastic-deformation work occurring at and below the inflection point is believed to represent the work required to propagate the crack through the biaxially-stressed sides and bottom of the test specimen where the plastic constraint is insufficient for cleavage. Thus, the temperature corresponding to the inflection point in the transition curve is believed to be (1) the maximum temperature at which a self-propagating (brittle) crack can initiate in a cross section of infinite dimensions, and (2) therefore a transition temperature which will be independent of specimen size and notch geometry.

Charpy bars of four cross sections (standard depth-half width, full width and double width; and half depth-double width) and three notch types (standard Charpy V notch, Charpy keyhole notch and half-depth V notch) were investigated. The inflection points occurred at the same temperature for all notch and specimen geometries. Thus, the tests show the low-blow transition temperature to be independent of notch and specimen geometry within the limits of notch acuity and specimen size investigated. Moreover, the strain-hardening and adiabatic-temperature rise associated with the crack-initiation stage of fracture have little or no effect on the low-blow transition temperature. And finally, although the reasoning on which the low-blow technique is based required the use of lateral-expansion measurements, the energy values read directly from the impact machine on delivering the crack-propagating blow can be used in determining the inflection point (low-blow transition temperature).

G. M. Orner is Mechanical Engineer and C. E. Hartbower is Physical Metallurgist associated with the Watertown Arsenal Labs., Watertown, Mass.

Introduction

Background

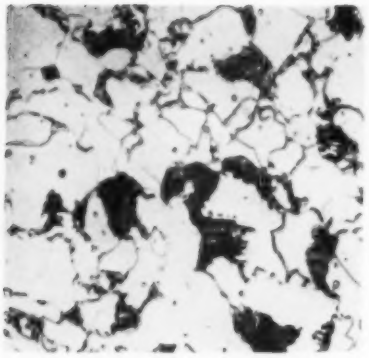
This report is the fifth of a series with the over-all objective of evaluating and improving the Charpy impact test. The findings reported in the four preceding papers[1-4] may be summarized as follows:

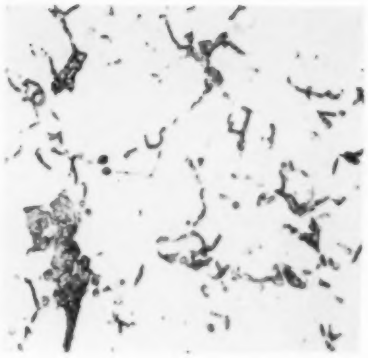
1. The lateral expansion occurring at the compression face of a Charpy bar (opposite the notch) bears a direct relationship to the energy absorbed in fracturing the specimen. This relationship is essentially linear in pearlitic steels and near linear in martensitic steels over a wide range of temperature.[1]

2. A basic distinction between ductile and brittle cracking, suggested by Orowan,[5] was applied to transition-temperature determinations in Charpy *slow-bend* testing. Transition temperature was defined as the highest temperature at which sudden and complete fracture occurred at maximum load, i.e., zero energy after maximum load. The definition was based on (*a*) an experimental observation by Raring[6] that the start of crack propagation in the thickness direction of the V-notch Charpy slow-bend bar coincides with the maximum in load as determined from the load-deflection diagram, and (*b*) the suggestion by Orowan that one may differentiate between ductile and brittle fracture by noting the manner in which the initiating crack is propagated—a brittle fracture is propagated by continuous release of the elastic stress field surrounding the crack, whereas a ductile fracture requires plastic-deformation work to extend the crack. Thus, with zero energy indicated by the load-deflection diagram after maximum load, fracture was considered to be brittle. Lateral expansion in the slow-bend bars which fractured suddenly and completely at maximum load was taken as a measure of the work done in initiating the crack.[2]

3. V-notch Charpy slow-bend and impact tests were conducted over a range of temperature to evaluate transition behavior in three commercial structural steels subjected to sub-critical heat treatment and a number of laboratory heats containing controlled amounts of carbon and manganese. From the conventional energy-temperature and fibrosity-temperature transition curves, it was evident that both the difference in deflection rate between slow-bend and impact, and the metallurgical variables introduced by composition affect the transition from ductile to brittle behavior. However, the conventional impact transition curves did not permit differentiation between the crack-initiation and crack-propagation stages of the fracture process. Moreover, it was apparent that because of the changes in shape of the transition curves produced by various metallurgical variables, conclusions drawn with respect to transition behavior were dependent on the choice of performance criteria and the definition of transition temperature. However, in slow-bend tests by focusing on the highest temperature permitting sudden and complete fracture at maximum load, it was possible to separate the crack-initiation and crack-propagation stages of the fracture process.[3]

4. In impact testing, a separation of the crack-initiation and crack-propagation stages was accomplished by means of an easily executed variation in the standard technique for Charpy impact testing. The procedure required initia-





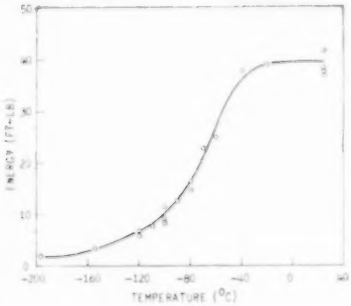


Fig. 1 Conventional energy temperature-transition curve and microstructure

A Nital etchant was used for the photomicrograph on the left, and the Cohen-Hurlich-Jacobson (Reference ASM Transactions 1947) reagent for the photomicrograph above. X 1000 (Reduced by 25% upon reproduction)

Fig. 2 Dial-gage instrument for measuring lateral expansion on Charpy bars

tion of a crack by means of a low-energy blow and then propagation of the crack by a second, full-capacity blow of the impact-machine pendulum. Lateral expansion attending the initial blow provided a measure of the plastic-deformation work done in initiating the crack, and the difference between the lateral-expansion measurements taken before and after the fracturing blow provided a measure of the work done in propagating the crack. Based on Orowan's concept, the temperature permitting crack propagation without plastic-deformation work was taken to be the brittle-fracture transition temperature.[4]

The concept of the highest temperature at which a brittle crack may propagate by energy released from the elastic stress field in the material surrounding the crack requires qualification. In the case of an edge crack in a uniaxially-stressed plate, the amount of elastic energy available for crack propagation may be shown to be proportional to the crack length by a simple derivation from the Griffith condition for a self-propagating crack. Thus, the highest temperature at which a crack can become self-propagating is a function of the length of the crack. Since the length of crack is small in a Charpy specimen, the amount of energy available for crack propagation in the Charpy bar can be considered to be of the same order of magnitude as that available at the *start* of brittle crack propagation in a full-scale structure.*

Purpose and Scope

The purpose of this investigation was to study the effect of notch and specimen geometry on Charpy impact transition temperatures as determined by the low-blow technique. In planning the investigation, it was hypothesized that if the Charpy low-blow transition temperature has fundamental significance, the transition temperature should be largely independent of notch acuity and specimen geometry.

Three types of notches were investigated, viz., the standard Charpy V notch, the standard keyhole notch, and a half-depth V notch for the half-depth specimens. The standard Charpy geometry was varied by halving the width (0.197 x 0.394 in.), doubling the width (0.788 x 0.394 in.), and doubling the width and halving the depth (0.788 x 0.197 in.).

Material

The material used in this investigation was a normalized pearlitic nickel steel in the form of a $1^3/_8$-in. thick rolled plate (chemical composition: 0.14%C, 0.50%Mn, 0.23%Si, 0.040%S, 0.017%P, 3.30%Ni). The conventional Charpy transition-temperature curve and the microstructure of this material are presented in Fig. 1.

Test Procedures

The first step in separating the crack-initiation and crack-propagation stages of fracture was to determine the minimum energy required to initiate cracking. This was accomplished by means of a low-energy blow. The crack-initiation energy was determined on the basis of the minimum low blow which produced a small but consistent depth of crack as evidenced by ink-staining.

* Under ordinary circumstances the stress raiser that may start a catastrophic service failure is small, such as the defects that occur in conjunction with welding (arc strikes, slag inclusions, incomplete penetration, etc.); the size of such flaws is generally of the same order of magnitude as a crack in the Charpy bar.

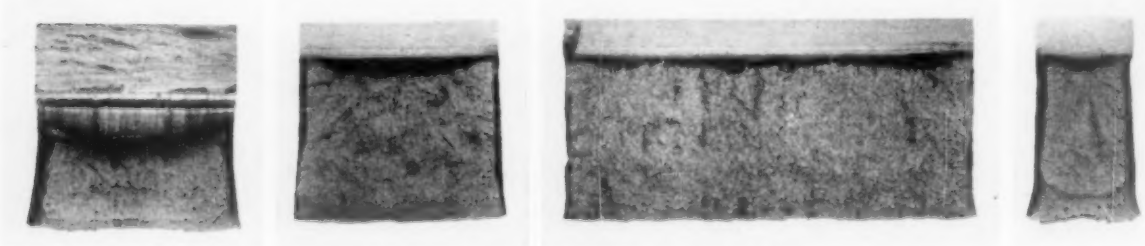


Fig. 3 Typical ink stains denoting crack initiation in various types of specimens. X 3

(India ink containing approximately 20% by volume of Kodak Photoflo solution as a wetting agent was used as a stain to determine the presence and extent of the initiating crack). The tests for determining the energy to initiate cracking were conducted at a single temperature (−80° C); both Harris, *et al.*,[3] and Hartbower[4] have shown the depth of low-blow induced crack to be essentially independent of temperature above the brittle-fracture transition.

Having established the minimum blow to produce consistently an ink-stained crack in each of the specimen geometries under investigation, a series of specimens of each geometry were struck crack-initiating low blows over a range of testing temperatures.* The specimens were then ink-stained. After allowing approximately twenty-four hours for the ink to dry, the specimens were fractured with a full-capacity blow at the same temperature as the crack-initiating blow.

Lateral-expansion measurements were made after each blow by means of the special instrument shown in Fig. 2. Comparisons between measurements obtained with this fixture and standard flat-anvil micrometers indicated that lateral-expansion measurements made on fractured Charpy bars with a micrometer were not sufficiently reproducible for the purposes of this investigation. The reason for the lack of reproducibility is that the fracture seldom passes through the exact center of the expanded portion of the specimen and, in some instances, the point of maximum expansion on one side of the specimen is located in one-half of the fractured bar, while the point of maximum expansion on the opposite side is contained in the other half of the bar. In such a case the lateral expansion as measured by a flat-anvil micrometer in each half of the test specimen is less than the true maximum width. By means of a dial-gage pointer and parallel-ground knife edges (Fig. 2), this source of inaccuracy was avoided. The lateral expansion on each side of each half of the test specimen was measured separately; thus, the sum of the higher values *from each side* provided the total lateral expansion. Even with this jig, care was required in making the measurements. In particular, all rough edges had to be removed from the specimen faces that were to come in contact with the knife edges; this was accomplished on a belt sanding machine using a fine grade of abrasive cloth (with care the material removed from the faces of the specimens was less than 0.0001 in.). Scatter experienced in the lateral expansion measurements obtained in the earlier investigations is believed to have resulted from the use of a standard micrometer.

* By definition of brittle cracking, elastic energy alone is required to propagate the crack at and below the transition temperature; therefore, fracture would be expected to occur as a result of the low blow in all cases where cracks are initiated in the brittle-fracture-temperature range. In practice a self-propagating crack does not always form as a result of the low blow. This is due to the fact that after the energy of the low blow has been expended in producing the plastic deformation required to initiate the ductile crack (which precedes cleavage-crack initiation), the pendulum velocity and hence the strain rate approach zero. Therefore, cleavage cracking does not always initiate from a low blow delivered at the transition temperature and below because plastic constraint, without the added effect of strain rate, is not always sufficient to raise the yield point to the cleavage-fracture strength level. However, whenever the low-blow-induced ductile crack does change to a crystalline crack under the initial low blow at and below the transition temperature, propagation is bound to follow.

Discussion of Results

The Crack-Initiating Low Blow

Figure 3 shows typical ink stains delineating the initiating crack in the various types of specimens investigated. In the standard-size V-notch Charpy specimens, a crack was considered to be initiated when it extended laterally

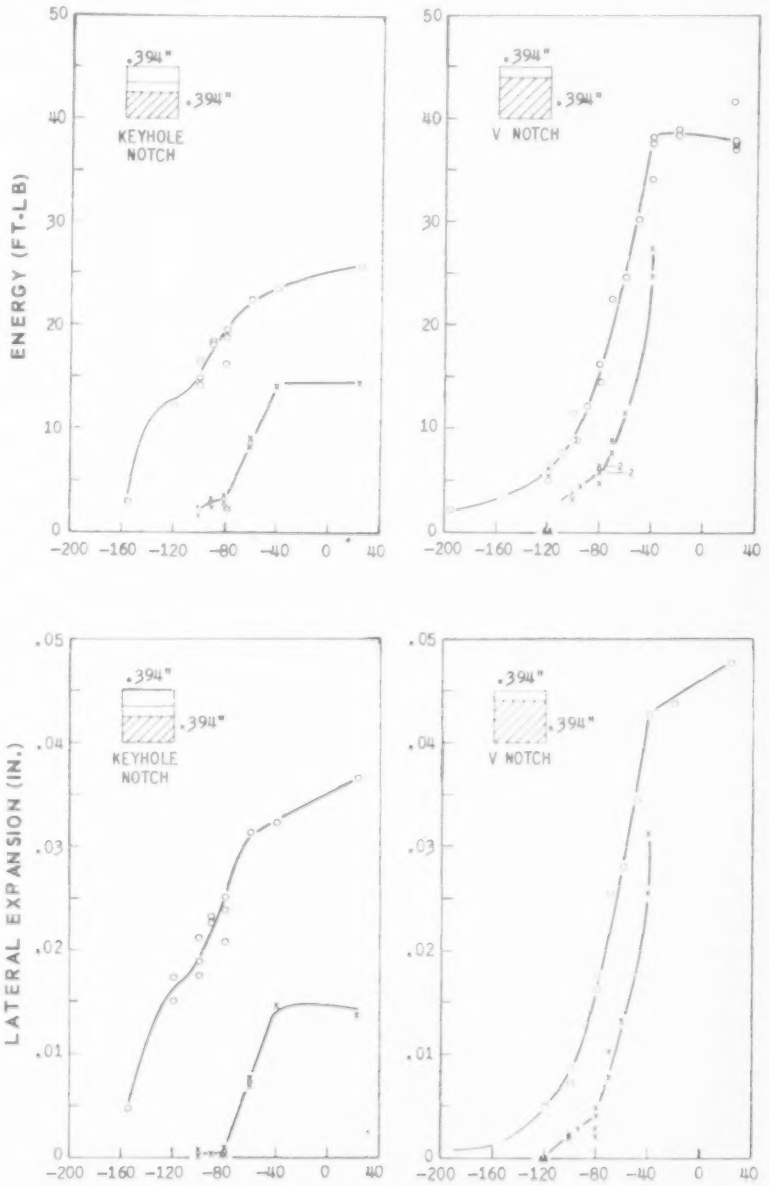


Fig. 4 Energy-temperature and deformation-temperature transition curves for standard V-notch and keyhole-notch Charpy specimens

The open circles (O) represent total energy or lateral expansion as obtained from a single full-capacity blow; the crosses (X) represent the energy or lateral expansion required to propagate the low-blow initiated crack; and the triangles (▲) indicate complete fracture of the specimens under the initial low blow. Note that the inflections denoting transition occur at −80° C in all cases

across the entire width of the test specimen.* In the case of the double-width V-notch Charpy specimen, like the standard specimen, the initiating crack was long and shallow of almost uniform depth extending laterally across the entire width of the specimen. In the one-half-width and the keyhole-notch specimens, the initiating crack propagated in the thickness direction before reaching the sides of the specimen.

The low-blow energy and attending lateral deformation required to initiate cracking (as determined by ink-staining) for the various specimen geometries and notches are listed in Table 1.

Where different widths of specimen (of the same depth) were tested, the crack-initiating energy was observed to be directly proportional to specimen width. In the case of the standard keyhole and V-notch specimens the energy to initiate cracking was observed to be approximately the same for both in spite of the considerable difference in depth of bar under the notch (0.315 in. under the V notch vs. 0.197 in. under the keyhole notch).

The function of the crack-initiating blow is to modify the notch by increasing its acuity so that, at and below the transition temperature, cleavage cracking will initiate with little or no plastic deformation when the specimen is struck

* In slow-bend tests of Charpy V-notch specimens, Raring[6] observed that crack initiation occurs as a ductile crack in the root of the notch at the midpoint of the specimen well before maximum load is reached; the crack then grows laterally as the load is increased until the crack reaches the sides of the specimen, at which time a maximum in the load-deflection diagram occurs; and finally, beyond maximum load the crack deepens while extending through the specimen.

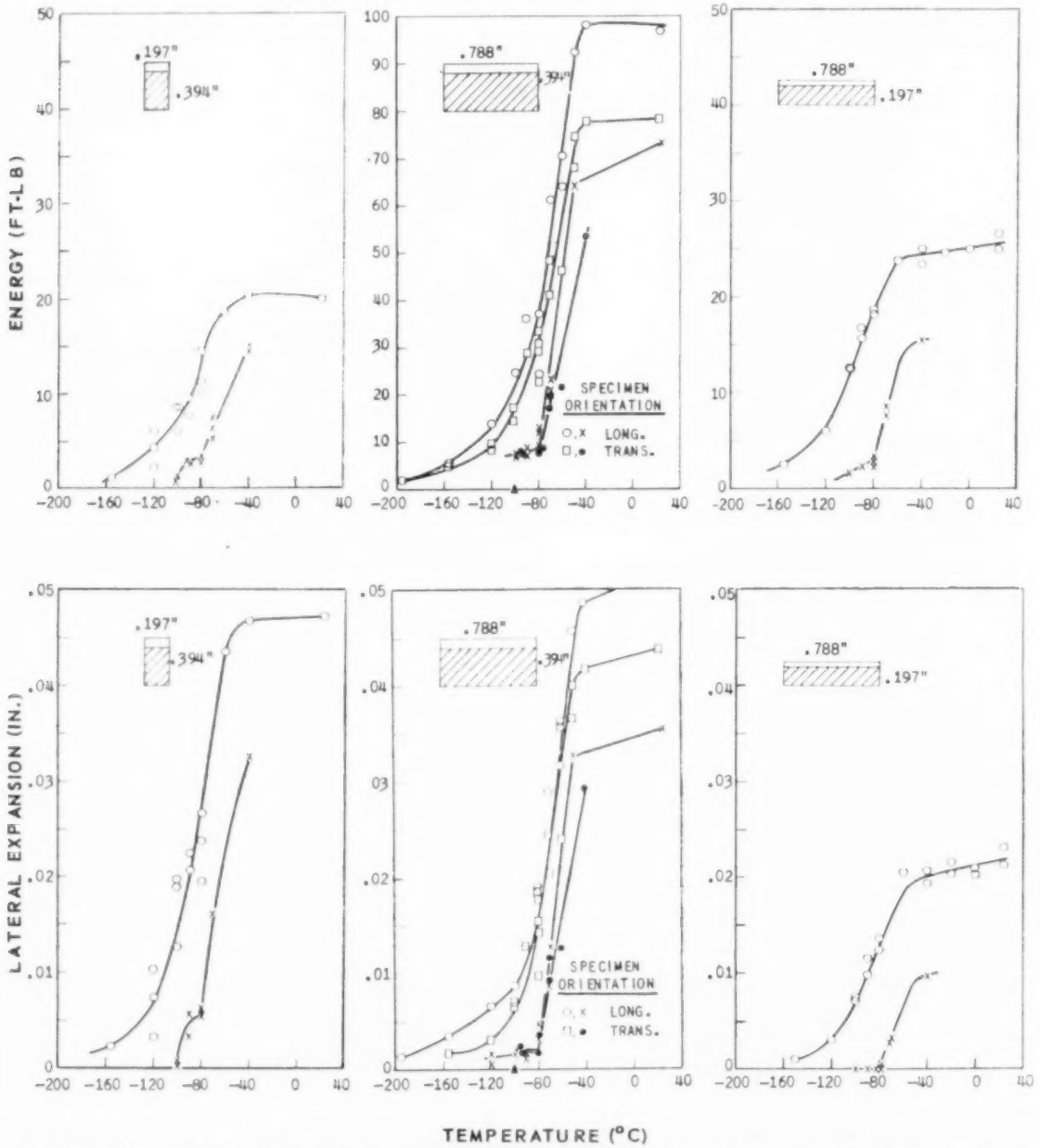


Fig. 5 Energy-temperature and deformation-temperature transition curves for various sizes of V-notch Charpy specimens

The open circles (O) represent total energy or lateral expansion obtained from a single full-capacity blow; the crosses (X) represent the energy or lateral expansion required to propagate the low- blow initiated crack; and the triangles (▲) indicate complete fracture under the initial low blow. Note that the inflections denoting transition temperature occur at −80° C in all cases

Table 1—Effect of Notch and Geometry on Crack Initiation

Notch type	Specimen size: depth, in.	Specimen size: width, in.	Initiating blow: energy, ft-lb	Initiating blow: deformation, in.
Keyhole	0.394	0.394	14	0.0198
V Notch	0.394	0.197	7	0.0130
V Notch	0.394	0.394	12	0.0108
V Notch	0.394	0.788	25	0.0098
V Notch	0.197	0.788*	15	0.0105
V Notch	0.394	0.788*	30	0.0110

* Specimen axis longitudinal to the direction of rolling.

a second full-capacity blow. Thus, after the crack-initiating low blow, although there remains a difference in depth between the Charpy keyhole and V notches, the difference in notch acuity no longer exists in that the bottom of both notches contains a natural crack.

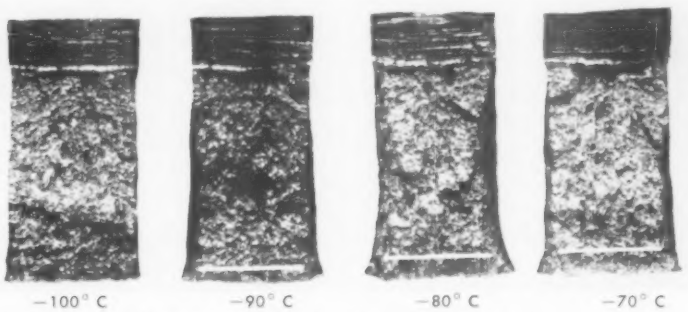
Work to Propagate the Initiating Crack

The lateral expansion associated with the crack-propagating blow and the energy absorbed in the crack-propagating blow were the criteria used in assessing the results of this investigation. Fracture appearance, being highly dependent upon strain rate, was not considered important to this report; it was noted, however, that the onset of cleavage (highest temperature permitting evidence of crystallinity in the fracture surface) occurred approximately 40° C above the brittle-fracture transition temperature.

Deformation-temperature and energy-temperature curves are displayed in Figs. 4 and 5. Two curves are presented on each plot: (1) the curve representing total energy or total lateral expansion as obtained by a conventional single full-capacity blow, and (2) the curve representing energy or lateral expansion associated with crack propagation as obtained by the low-blow technique. All curves determined by the low-blow technique show a rapid fall off in the work required to propagate the crack and an inflection at −80° C.

The lateral-expansion values at and below the inflection point in the curves obtained by the Charpy low-blow technique are considered to represent the work required to propagate the crack through the ductile areas at the sides and bottom of the specimen where the plastic constraint is insufficient for cleavage-type cracking. This hypothesis is based on the following observation: the amount of shear cracking at the sides and the fibrosity at the bottom edges of the test specimens appear to correlate with the rate of decrease of lateral expansion occurring below the inflection point in the deformation-temperature curves of Figs. 4 and 5. Note, for example, that the deformation below the inflection point in the curve for the half-width specimen in Fig. 5 falls off to zero at −100° C. The fracture surfaces in the half-width specimens, illustrated in Fig. 6, show the decrease in shear and fibrosity as temperature was lowered until at −100° C they almost disappear. The keyhole-notch and the 0.197-in. x 0.788-in. specimens showed little or no fibrosity at and below the transition temperature, correlating with the low or zero values for lateral expansion occurring with these specimens during crack propagation in this temperature range.*

* Although the energy-temperature transition curves obtained by the low-blow technique also showed distinct inflection points, the energy values at and below these points included elastic energy and such losses as occur from friction, brinelling, kinetic energy imparted to the specimen, etc. Thus, in contradistinction to the lateral expansion measurements in the keyhole and half-depth double-width specimens, the energy values at the inflection point are never expected to be zero.



−100° C −90° C −80° C −70° C

Fig. 6 Shear and fibrosity at and below the inflection point

Note that the ductile areas decrease with decreasing temperature and nearly disappear at −100° C. From Fig. 5 (lower left) it may be seen that the lateral expansion approaches zero at −100° C. X 4

Thus, at the temperature corresponding to the point of inflection, plastic-deformation work was required to propagate the crack at the free surfaces only; whereas, the crack in the center portion of the specimen cross section was propagated by continuous release of elastic-strain energy. Since the elastic energy in stressed Charpy specimens of varying geometry but equal length is approximately proportional to their cross-sectional areas, and brittle cracks are propagated at the transition temperature by this elastic energy, it follows that the energy per unit area required for brittle crack propagation in the center portion of the specimen cross section is essentially independent of specimen size; hence, it is independent of the distance of the propagating crack from the surface. Therefore, brittle-crack propagation in the center portion of a Charpy specimen cross section is analogous to brittle-crack propagation in a cross section without surfaces, viz., a cross section of infinite dimensions. The low-blow transition temperature is therefore believed to be of fundamental significance, i.e., the maximum temperature at which a self-propagating crack can initiate in a cross section of infinite dimensions.

Although the data show that low-blow transition temperatures are independent of specimen size within the limits tested, smaller specimens may be expected to indicate lower transition temperatures as a result of insufficient plastic constraint to initiate cleavage cracking at the transition temperature. An example of the delayed initiation of cleavage cracking due to insufficient plastic constraint may be seen in Fig. 7 where the temperature corresponding to the onset of crystallinity is plotted against lamina thickness. These data are from an investigation by S. V. Arnold[8] in which laminated V-notch Charpy specimens 0.394-in. deep x 0.400-in. (over-all) wide were broken by a single full-capacity blow. The laminae (1-8 per specimen) were held together with rivets, and notches were cut across the edges of the laminae. During fracture each lamina behaved independently except for the mutual lateral support they afforded each other. As the number of laminae was increased, their reduced individual thicknesses resulted in a reduction of plastic constraint and a lowering of the temperature at which cleavage cracking first occurred. The curve suggests that 0.200 in. was a critical width for the particular steel investigated; i.e., maximum plastic constraint may not be developed in Charpy V-notch specimens less than 0.2 in. wide.

The presence of crystallinity at temperatures above the low-blow transition temperature is an indication that the plastic constraint was adequate for the

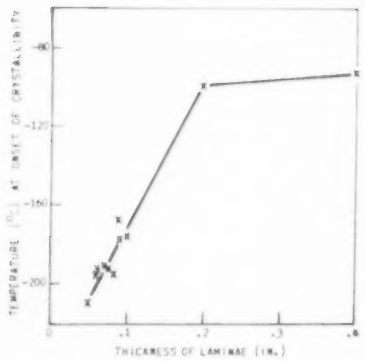


Fig. 7 Effect of thickness on the temperature corresponding to the onset of crystallinity

Specimens consisted of laminated Charpy bars (data from an investigation by S. V. Arnold, Reference 8). Note that the temperature at the onset of crystallinity decreases linearly with decrease in laminar thickness below 0.2 in.

purposes of the test. If crystallinity does not occur at temperatures above the inflection point, the inflection does not necessarily represent a temperature that is significant in terms of crack propagation in a cross section of larger dimensions.

Conventionally-obtained data (single full-capacity blow) from standard-depth Charpy specimens of one-half, standard and double widths (replotted from Figs. 4 and 5) tend to support the observation that a 0.2-in. width may be critical (Fig. 8). Note that increasing the width of bar from 0.394 in. to 0.788 in. had little or no effect on the deformation-temperature transition curve; whereas, decreasing the width to 0.197 in. caused a slight shift in the curve to a lower temperature.

An important factor affecting laboratory transition-temperature determinations is the adiabatic-temperature rise associated with the plastic-deformation work occurring during the crack-initiation stage of fracture. The magnitude of this temperature rise may be 20° C or more (this will be discussed further with supporting experimental evidence in a report to follow). In the low-blow method of transition-temperature determination adiabatic-temperature rise during crack initiation is eliminated as a factor affecting crack propagation in that the specimens are recooled before the crack propagating blow is struck. Another variable inherent in most laboratory transition-temperature determinations is the effect of strain hardening during the crack-initiation stage. Strain hardening tends to raise transition temperature; however, the effect of strain hardening on the low-blow transition appears to be insignificant. This is indicated by the finding of the same values for transition temperature for both the keyhole and V-notch specimens in spite of the fact that approximately twice as much plastic deformation was associated with crack initiation in the keyhole-notch specimens as compared with the V-notch specimens. An explanation for the fact that strain hardening does not affect low-blow transition-temperature determinations is that the fracture has to pass through the central unstrained portion of the test specimen (Fig. 9); the plastic-deformation work required to propagate the crack cannot be minimized until the specimen has been cooled down to the transition temperature of the unstrained material.

Apart from the root of the notch where cracking initiates, the areas of maximum strain occur at the compression face and the unconstrained sides of the specimen. As previously stated it is the plastic-deformation work required to propagate the ductile crack through these areas that is thought to be responsible for the lateral expansion occurring at and below the inflection in the V-notch low-blow deformation-temperature curves. Since essentially no lateral expansion occurs at the inflection in the Charpy keyhole curves, it appears likely that the strain hardening resulting from the crack-initiating blow has sufficiently embrittled the material at the free surfaces of the keyhole specimens to allow brittle cracking to take place at the inflection temperature in spite of the lack of plastic constraint. This characteristic of the keyhole specimen results in a sharply defined point of inflection. The lateral-expansion curve for sub-depth V-notch specimens (0.197-in. deep x 0.788-in. wide) displays the same phenomenon, and although the lateral expansion during crack initiation was approximately the same as with the full-depth V-notch specimens, it can be shown by the "law of similitude"[9] that a smaller volume of metal was deformed and percent-strain values were therefore higher.

Conclusion

An easily executed variation in the standard technique for testing Charpy impact specimens has been developed which permits a separation of the crack-initiation and crack-propagation stages of the fracture process.

The transition temperature so obtained is thought to represent the maximum temperature at which a self-propagating crack can initiate in a cross section of infinite dimensions. Within the limits of specimen size and notch types used in this investigation, the low-blow transition temperature is independent of specimen size and notch type. Moreover, the effects of strain hardening and adiabatic-temperature rise associated with the crack-initiation stage of fracture are of little or no

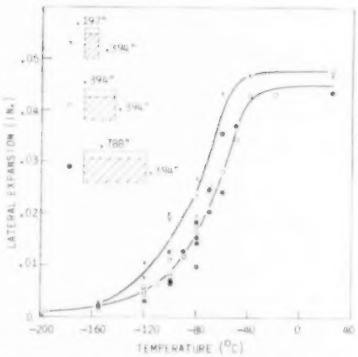


Fig. 8 Deformation-temperature curves for conventionally impacted standard-depth specimens in half (x), standard (o), and double (●) widths

Note that the data for the standard and double-width specimens fall on practically the same curve while the data for the half-width specimens are displaced to a slightly lower temperature

consequence in the transition-temperature determinations when this method is used.

Although the reasoning on which the low-blow technique is based required the use of lateral-expansion measurements, the conventional energy measurement may be used without altering the transition-temperature determination.

Future Work

The low-blow method of transition-temperature determination as described herein would be greatly simplified if the crack-initiating blows were struck at room temperature, as this modification in procedure would facilitate obtaining data below the transition temperature. The effect, if any, of the temperature at which the crack-initiating blow is struck

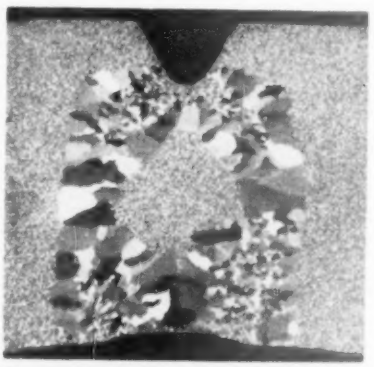


Fig. 9 Strain distribution in the center of a V-notch Charpy bar after impact with a low-energy blow

This section, from a V-notch Charpy bar cut from 0.04%C steel, was struck a 30 ft-lb low blow and annealed for 45 hr at 850° C to promote abnormal grain growth in the plastically-deformed areas. The specimen was subsequently sectioned, polished, and etched and indicates the central area where little or no plastic deformation has taken place

on the low-blow transition-temperature determinations should therefore be investigated. Moreover, additional materials will have to be investigated using the low-blow technique (a quenched-and-tempered martensitic steel and an additional pearlitic steel were under investigation at the time of this reporting—the nearly completed tests on the martensitic steel appear to fully substantiate the findings reported herein).

Acknowledgment

The authors wish to acknowledge, with thanks, the assistance given by Mr. T. N. Armstrong of the International Nickel Company in providing the nickel-steel plate used in this investigation.

References

1. Hartbower, C. E., "The Poisson Effect in the Charpy Test," presented at the 57th Annual Meeting of The American Society for Testing Materials; *ASTM Proceedings*, Vol. 54, p. 929 (1954).

2. Hartbower, C. E., "Transition Behavior in V Notch Charpy Slow-Bend Tests," presented at the 58th Annual Meeting of ASTM; WAL Report TR-112.87-1 dated 29 May 1956; ASTM Symposium on Impact Testing (1955), Special Technical Publication No. 176.

3. Hartbower, C. E., "Effect of Selected Metallurgical Variables on Transition Behavior in V-Notch Charpy Slow-Bend and Impact Tests," WAL Report TR-112.87-2 dated February 1957.

4. Hartbower, C. E., "Crack Initiation and Propagation in the V-Notch Charpy Impact Specimen," presented at the 59th Annual Meeting of ASTM; WAL Report TR-112.87-3 dated March 1957.

5. Orowan, E., "Fracture and Strength of Solids," Physical Society of London Reports on Progress in Physics, Vol. 12, 185–232 (1949).

6. Raring, R., "The Load-Deflection Relationship in Slow-Bend Tests of Charpy V Notch Specimens," presented at the 55th Annual Meeting of ASTM; *ASTM Proceedings*, Vol. 52, p. 1034 (1952).

7. Harris, W. J., Rinebolt, J. A., and Raring, R., "Upper and Lower Transitions in Charpy Test," THE WELDING JOURNAL **30** (9), p. 417-s (1951).

8. Arnold, S. V., "A Proposed Method for Impact Testing of Sheet Metal," WAL Report 112.90 dated July 1956.

9. Sachs, G., "Some Fundamentals of the Flow and Rupture of Metals," *Trans. AIME* **143** (12) (1941).

RESEARCH NEWS

X-Ray Diffractometer

A new Norelco X-ray diffractometer, redesigned with a number of changes which are said to extend sensitivity, accuracy and application range of the instrument, has been announced by the Instruments Division, Philips Electronics, Inc., 750 S. Fulton Ave., Mount Vernon, N. Y.

Developed especially for X-ray powder diffraction work, the unit can re-

portedly accommodate high and low temperature chambers, devices for preferred orientation and pole-figure studies, focusing monochromators and similar accessories.

The new diffractometer is said to save time for the diffractionist through the use of higher intensities, automatic recording features, minimized service problems and easy alignment.

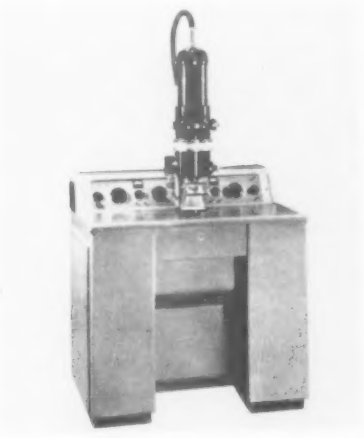
Three components comprise the assembly: 1. Basic X-ray generator and tube. 2. Wide-range goniometer with detector. 3. Electronic circuit panel with strip-chart recorder.

In use, the goniometer is placed on the table top of the basic generator and this assembly then measures approximately 30 in. wide, 70 in. high, 28 in. deep and weighs 856 lb. The circuit-panel cabinet is 20 in. wide, 71 in. high, 23 in. deep and weighs 509 lb.

The goniometer reportedly accommodates scintillation, proportional, flow or Geiger counter units to provide a wide choice of detectors for all conditions. A single-channel pulse-height analyzer is included in the circuit panel when required by the user.

Electron Microscope

A Norelco Electron Microscope (EM-75-B) for analytical work in industrial processing and research has been announced by the Instruments Division, Philips Electronics, Inc., 750 S. Fulton Ave., Mount Vernon, N. Y.



Objective lens has an externally adjustable mechanical compensator with a single control, indexed and coupled to double dipoles positioned on the face of the pole shoe. Transmission electron diffraction patterns are obtained through a simple lens current adjustment.

The new instrument permits stereo images to be produced by rotating the specimen rod under vacuum. Magnification is continuously variable and can be varied from 1200–12,000 diameters on the screen. According to the manufacturer, resolving power is better than 50 Angstroms.

High voltage supply is continuously variable from 20 to 75 kv. Screen image is 90 x 90 mm at all magnifications. An image viewing magnifier (×2) mounted on a swivel or a binocular attachment (×8) with metal viewing chamber and camera are interchangeable accessories.

Film cassette accommodates up to 36 indexed exposures on film without changing camera, or 8 plates with metal viewing chamber and camera. Micrographs are 28 x 28 mm standard fine grain film or 3¼ x 4-in. glass plates.

Useful photographic enlargements may be made up to ×50,000 using 35-mm film or ×100,000 using glass plates. The objective aperature is demountable for cleaning and has a 3-dimensional adjustment.

Titanium

The Notch Toughness of Weld Deposits in Commercial Titanium Alloys. D. M. Daley, Jr. and C. E. Hartbower, Watertown Arsenal, U. S. Army. July 1956. 31 pages. (Order PB 131109 from OTS, U. S. Department of Commerce, Washington 25, D. C., $1). Weldments prepared in commercial titanium and titanium alloys by the inert-gas-shielded consumable-electrode process were tested for weld metal toughness at varied temperatures by use of the V-notch Charpy impact specimen. Base materials were heats of unalloyed titanium and heats containing manganese and chromium plus iron. Welding electrodes were unalloyed titanium, except for single heats of Ti-7Mn and Ti-4Cr-2Fe. It was observed that weld deposits in unalloyed titanium plate de-

(Continued on page 549-s)

A NEW NICKEL-BORON PHASE DIAGRAM FOR BRAZING-ALLOY DEVELOPMENT

New determination of phase relationships in the nickel-rich end of nickel-boron system is reported upon by the author

BY G. S. HOPPIN III

SYNOPSIS. A new determination has been made of the phase relationships in the nickel-rich end of the nickel-boron system. A partial phase diagram is presented. The eutectic temperature was found to be 1980° F, or 100° F lower than the value published in the metallurgical literature. A small region of solid solubility of boron in nickel was also found. The literature does not report this. The information obtained should be of value in the development and application of nickel-base high-temperature brazing alloys containing boron.

Introduction

The past several years have witnessed the introduction and growing use of oxidation and corrosion-resistant nickel-base brazing alloys. The materials of this class most commonly used have been alloys in the following systems: Ni-Cr-Si-B (AWS BNiCr, AMS 4775, AMS 4778); Ni-Si-B (AMS 4777) and Ni-Cr-Si (General Electric 81). Most of the boron-bearing alloys were originally designed as hard-surfacing materials. The Ni-Cr-Si alloy was specifically designed to eliminate boron, which is intolerable in certain nuclear applications, due to its high neutron capture cross section. For certain jet-engine applications involving the brazing of very thin heat-resistant alloys, all of these materials possess certain drawbacks. The boron-bearing alloys tend to dissolve the base materials excessively, and the boron-free alloy has an excessively-high brazing temperature (2200° F). Consequently, programs aimed at developing superior nickel-based brazing alloys have been instituted by the Aircraft Gas Turbine Division of General Electric. At the start of these programs, it was felt that boron-containing alloys could be used provided the boron content was considerably lower than the 2.5–4.5% present in the AMS 4775 and 4777 alloys. This level had primarily been dictated by the origin of these alloys as hard-surfacing materials.

G. S. Hoppin is associated with the General Electric Co., Flight Propulsion Laboratory Department, Aircraft Gas Turbine Division, Cincinnati, Ohio.

In attempting to design new nickel-based brazing alloys, the binary phase diagrams available in the metallurgical literature were used. Determinations of solidus and liquidus temperatures made on a few experimental alloys tended to indicate that the literature was incorrect on Ni-B phase relationships at various temperatures. It was therefore decided to perform a new determination of Ni-B phase relationships in the low-boron region of the system. Binary alloys were melted of virgin materials, precisely analyzed chemically, and phase boundaries determined by thermal analysis and metallographic studies.

Preparation of Alloys

For this work, five 10-lb heats of binary Ni-B alloys were melted in our laboratory, and three 10-lb heats were procured from a commercial source. One additional 10-lb heat containing 8.5% chromium was melted by our laboratory to determine what effect this element might have on solidus and liquidus temperatures. The alloys melted by our laboratory ranged from 0.01 to 1.81% boron, and the commercial source alloys covered the range 1.84–3.68% boron.

Melting of alloys in our laboratory was done in a magnesia crucible high-frequency induction furnace under a blanket of flowing argon. Commercially-pure electrolytic nickel and a nickel-boron master alloy were used as raw materials. The master alloy contained the following maximum amounts of impurities: carbon —0.18%, iron —0.42%, silicon —0.39%, aluminum —10%. These impurity levels were considered low enough to neglect in the nickel-boron alloys, where total impurity content was diluted to less than 0.03%.

Precise wet chemical analyses for boron were performed on all the alloys prepared. Results of these analyses are given in Table 1.

Phase - Boundary Determination Methods

To provide cross-checks on the data obtained, three separate methods were used to determine the temperatures at which phase boundaries were crossed. These methods were: pellet melting, continuous cooling curves and metallographic studies of water-quenched samples. A brief description of each method follows:

Table 1—Chemical Analyses of Ni-B Alloys

Alloy	*Nominal boron content, wt %*	*Analyzed boron content, wt %*
NB-1	0.1	0.0125
-2	0.3	0.30
-3	0.5	0.51
-4	1.0	0.89
-5*	1.5	1.34
-6	2.0	1.81
-7	2.0	1.84
-8	3.0	2.93
-9	4.0	3.68

*Chromium (8.49%) also present.

Pellet melting consisted of simply heating small pellets of the binary alloys to successively higher temperatures in purified (−90° F dewpoint) hydrogen. The pellets were placed on clean steel panels. To avoid obscuring results by any changes in composition occurring through solid-state diffusion of boron, only one pellet of each alloy was run at each temperature. Solidus and liquidus temperatures were estimated to within 10° F by visual examination. Ascending intervals of 25° F were used in heating the samples, which were held for ten minutes at temperature. All temperatures were checked with a Chromel-Alumel thermocouple placed immediately adjacent to the samples in the furnace retort. A 3-in. inside diameter tube furnace, heated by silicon carbide elements and equipped with an Inconel atmosphere muffle, was used for all experiments performed in this work.

The first experiments run were with alloys in powder form pressed to 1/4-in.

diam pellets. It soon became apparent that solidus temperatures could be accurately determined, although liquidus temperatures could not, since the pellets would collapse when about 50% liquid phase was present. Consequently, only solidus temperatures were determined by this technique.

Continuous cooling curves were obtained on five of the alloys with a strip recorder and a Pt–Pt10% Rh thermocouple in a silica protection tube. The curves were obtained immediately at the conclusion of induction melting. After complete solidification had taken place, the alloys were remelted and a second curve obtained before pouring the alloys. Solidus and liquidus temperatures estimated from the thermal arrests in these cooling curves are considered to be the most accurate of the values obtained in this investigation.

Metallographic studies of water-quenched samples were made to establish accurately the eutectic temperature and to determine the solid-solubility limits of boron in nickel. Solid cast pellets of the five alloys used for cooling curve determinations were heated in air to various temperatures (in 50° F increments) for 30 min and then water quenched to retain the high-temperature phases.

Table 2—Solidus and Liquidus Temperatures Determined on Nickel-Boron Binary Alloys

Alloy	*% Boron*	*Solidus, ° F* A*	B†	C‡	*Liquidus, ° F* A*
NB-1	0.0125	2520			2630
-2	0.30	2015		2225	2580
-3	0.51	2020		1975	2540
-4	0.89	1980		1975	2485
-5	1.34		1980		
-6	1.81	1980		1975	2305
-7	1.84		2010		2305
-8	2.93		1995		
-9	3.68		1980		

* A = Determined from continuous cooling curves.
† B = Determined from pellet melting studies.
‡ C = Determined from metallographic studies of water-quenched samples.

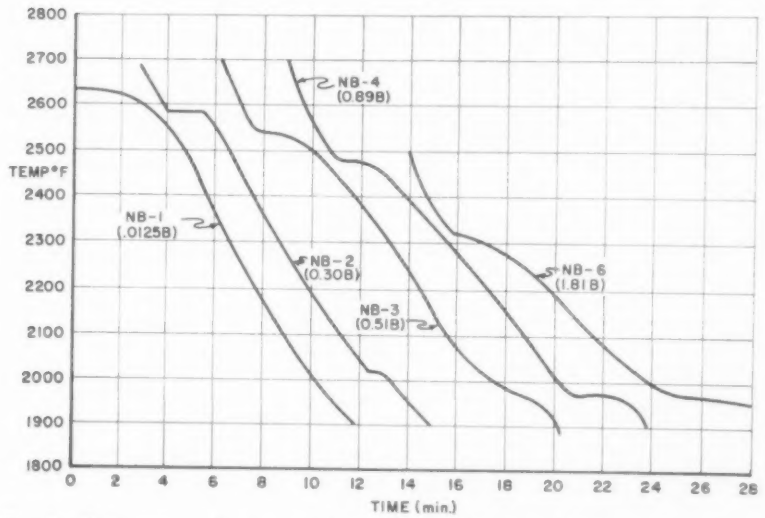


Fig. 1 Continuous cooling curves determined on five nickel-boron alloys

Results of Liquidus and Solidus Temperature Determinations

Pellet melting studies were performed on alloys NB-5, -7, -8, -9. Estimated solidus temperatures for these alloys (1.34–3.68% B) were 1980–2010° F.

Continuous cooling curves were made on alloys NB-1, -2, -3, -4, and -6. The curves obtained are shown in Fig. 1. Solidus temperatures for the alloys in the range 0.30–1.81% B were 1980–2020° F.

Metallographic studies located solidus temperatures for alloys NB-3, -4, and -6 (0.51–1.81% B) as being between 1950 and 2000° F.

A summary of all liquidus and solidus temperatures determined is presented in Table 2.

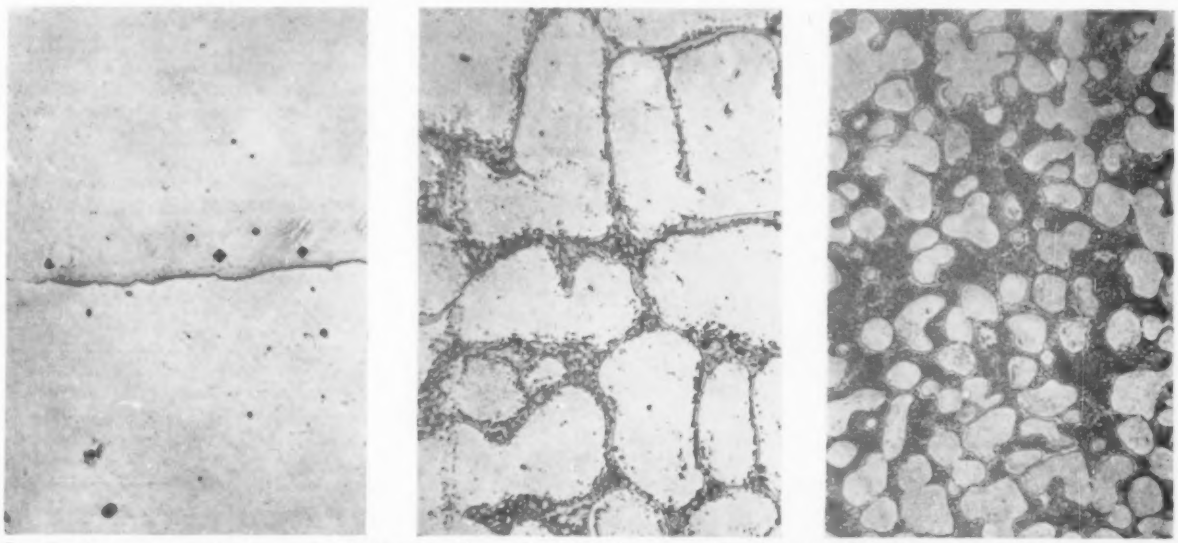


Fig. 2 As cast microstructures of nickel-boron alloys: (*left to right*) Alloy NB-1 (0.0125%B); Alloy NB-3 (0.51%B); Alloy NB-6 (1.81%B). Etchant: electrolytic 10% KOH. X 250

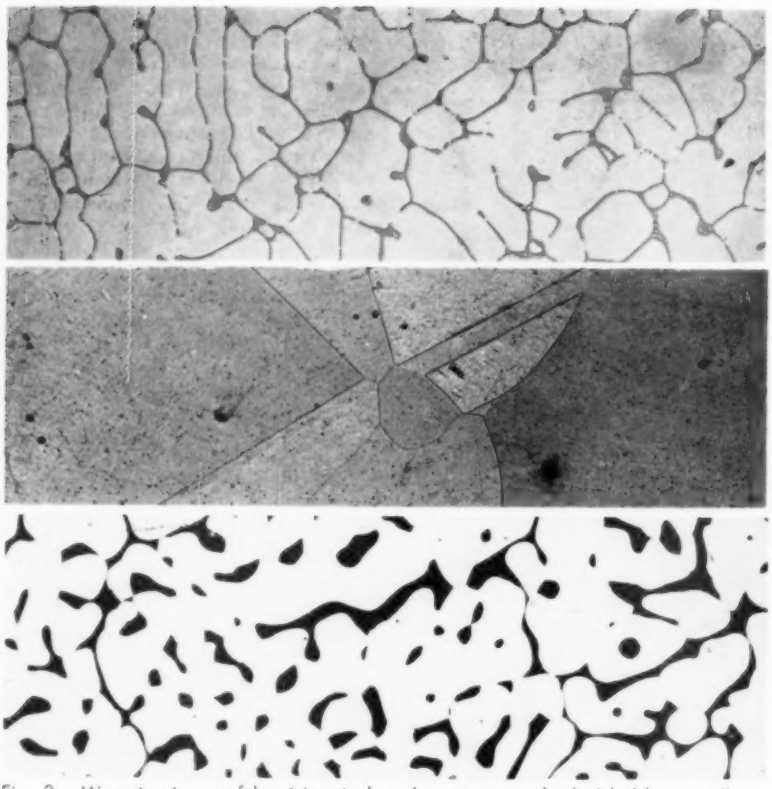


Fig. 3 Microstructures of heat-treated and water-quenched nickel-boron alloys. Etchant: electrolytic 10% KOH. Magnification: X 100. (Top) Alloy NB-2 (0.30% B) quenched from 1900° F; structures: α solid solution plus primary eutectic. (Center) Alloy NB-2 (0.30%B) quenched from 2150° F; structure: α solid solution. (Bottom) Alloy NB-3 (0.51%B) quenched from 2000° F; structures: α solid solution plus resolidified liquid

Metallographic Studies

Metallographic examination of the water-quenched cast slugs from five alloys made it possible to estimate the phase boundaries of the α solid solution of boron in nickel. As-cast structures of all alloys save NB-1 (0.0125% B) showed the presence of the primary nickel-boron eutectic. Figure 2 shows three typical as-cast structures. Upon heating and water quenching the specimens, three distinct types of structures were observed. These were: (1) α solid solution plus primary eutectic, (2) α solid solution and (3) α solid solution plus resolidified liquid. Figure 3 shows these structures.

The α plus primary eutectic structure is stable below the solid-solution zone and below the eutectic temperature, while the α plus resolidified liquid structure indicates that the sample was heated into the solid solution plus liquid zone of the phase diagram.

Solid-solution structures were uniformly observed on heating alloy NB-1 (0.0125% B) up through 2300° F. A transition from α plus primary eutectic to all alpha was observed on alloy NB-2 (0.30% B) between 1900 and 1950° F. This solid solution was stable to 2200° F, a transition to α plus resolidified liquid occurring between 2200 and 2250° F. Alloys NB-3 (0.51% B), NB-4 (0.89% B) and NB-6 (1.81% B) exhibited no solid-solution range and all showed a transition from alpha plus primary eutectic to alpha plus resolidified liquid between 1950 and 2000° F.

New Equilibrium Diagram

Taking all of the various observations and measurements into account, it appears that the major features of the nickel-rich end of the nickel-boron equilibrium diagram are as follows: (1) a eutectic temperature of 1980° F, (2) a eutectic composition of about 3.5% boron (by extrapolation) and (3) a maximum solid solubility of boron in nickel of 0.7% at 1980° F.

This declines to 0.3% at 2225 and at 1925° F.

The portion of the phase diagram determined is shown in Fig. 4. It should be noted that there was some conflict between the various data obtained in the region of maximum solid solubility of boron in nickel, but the major features of the new diagram are believed correct.

The significance of this partial diagram is realized when it is compared to the only one currently available in the

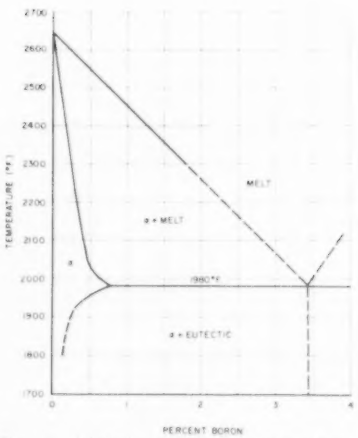


Fig. 4 Nickel-rich region of the nickel-boron equilibrium diagram

metallurgical literature. The latest available compilation of all equilibrium diagrams is that of Smithells (Metals Reference Book, Vol I, Interscience Publishers, NYC, 1955). The nickel-boron equilibrium diagram shown in this compilation indicates no solid solubility of boron in nickel, a eutectic temperature of 2085° F and a eutectic composition of 4% boron. By tracing through the literature, it was discovered that the source of this information was the work of a German named Giebelhausen in 1914. The difference in the results presented from those obtained in the earlier work is unquestionably the product of 40 odd years improvement in pyrometry and chemical analysis techniques.

Significance to Brazing-Alloy Development

The purpose behind the investigation related was to obtain information on Ni-B phase relationships that might be used for brazing-alloy development and application. Two significant items were learned which should assist in these purposes. First, the eutectic temperature was found to be 100° F lower than previously reported. Second, it was established that boron does have a finite solubility in nickel.

Knowing the true eutectic temperature is of great importance in certain jet-engine and rocket applications, where temperatures circa 2000° F may be reached on brazed parts. The eutectic temperature and composition also serve as a guide in determining additions of boron to lower the melting point of nickel in high-temperature brazing alloys.

To achieve maximum high-temperature strength in nickel-alloy brazed joints, diffusion treatments to remove boron from the joint are sometimes used. The establishment of the borders of the boron solid solution in nickel should indicate what boron levels in nickel-alloy brazed joints are permissible to avoid remelting of the eutectic at 1980° F.

STUDIES OF THE WELD HEAT-AFFECTED ZONE OF T-1 STEEL

Investigation indicates that slow cooling rates after welding, such as may result from either high energy input or high initial plate temperature have a damaging effect upon the notch toughness in the heat-affected zone of T-1 steel

BY E. F. NIPPES, W. F. SAVAGE AND R. J. ALLIO

ABSTRACT. It is axiomatic that, in the case of hardenable steels, rapid cooling after welding is undesirable because of the formation of brittle martensite. However, in the case of T-1 steel, it has been demonstrated that rapid cooling after welding has little effect upon the impact performance of the heat-affected zone. This may be explained by the presence of low-carbon martensite, a constituent with good notch toughness.

If cooling rates after welding T-1 steel are reduced, a deterioration in notch toughness may be expected, since structures other than that of low-carbon martensite will be formed. It was the ultimate objective of this investigation to determine the effect of slow cooling rates, such as would result from high energy input and high initial plate temperature, on the properties of the heat-affected zone.

Thermal cycles experienced in the heat-affected zone of T-1 welded under conditions of high energy input were measured by oscillographic techniques. Thermal cycles experienced after welding with various preheats were calculated from previous data. From a knowledge of these thermal cycles, it was possible to prepare synthetic specimens simulating the structure at several points in the heat-affected zone under a variety of welding conditions. The impact performance and hardness of these specimens were determined and correlated with structure. To expedite analysis of microstructure, the continuous-cooling transformation behavior of T-1 was determined by thermal analysis and by high-speed dilatometry. To verify the validity of the synthetic-specimen technique, microstructures of the synthetic specimens were checked against microstructures of actual weld specimens.

It was concluded that the slow cooling rates arising from welding with either high energy input or high initial plate temperature have a detrimental effect upon notch toughness in the heat-affected zone of T-1 steel. This loss in notch toughness can be attributed to the existence of a microstructure consisting of martensite and bainite in a matrix of ferrite. Satisfactory notch toughness, as defined by the ability to absorb 10 ft-lb of energy at −50° F, requires a minimum cooling rate after welding of 6.5° F/sec at 900° F. The weld-energy input and initial plate temperatures that produce this cooling rate were calculated for various plate thicknesses.

E. F. Nippes and **W. F. Savage** are associated with the Dept. of Metallurgical Engineering, Rensselaer Polytechnic Institute, Troy, N. Y.; and **R. J. Allio** is Engineer at Knolls Atomic Power Laboratory, General Electric Co., Schenectady, N. Y.

This paper is based on a thesis presented by R. J. Allio in partial fulfillment of the requirements at RPI for the degree of Ph.D. in Metallurgy.

Introduction

In recent years, a number of new constructional steels have been developed for applications requiring high yield strength, good weldability, and good low-temperature toughness. Considerable work has already been done on the evaluation of one of these materials, T-1 steel, a low-alloy steel used in the quenched-and-tempered condition. Results of laboratory and field tests on T-1 steel have been reported in the literature.[1–5]

In the case of hardenable steels containing moderate amounts of carbon, the rapid cooling rates associated with ordinary weld-thermal cycles generally cause formation of brittle martensite in the heat-affected zone. The presence of the martensite is invariably accompanied by a deterioration of notch toughness in this region. Since post-heating is not always possible, the alternative solution requires a reduction of the cooling rates after welding by either preheating or by increasing the energy input during welding.

For alloy steels containing low percentages of carbon, on the other hand, notch toughness may be high in the as-welded state, even in the absence of preheat or high energy inputs. This good toughness may be explained by the presence of low-carbon martensite, which, as Aborn[6] has shown, has excellent properties in the quenched condition. Verification of the satisfactory impact strength of T-1 in the as-welded state has been performed by Nippes and Sibley.[5]

The favorable mechanical properties of T-1 are actually contingent upon the existence of low-carbon martensite. Thus, it is not unreasonable to postulate that preheat or high energy inputs are, in fact, detrimental to the notch toughness of T-1. Both of these factors lower cooling rates after welding and consequently tend to produce microstructures other than that of low-carbon martensite.

In practice it is found that pressure-vessel steels, such as T-1, are often preheated prior to welding. This may be done by the fabricator as a matter of custom, or to minimize the effect of hydrogen, a potential source of underbead cracking. Furthermore, if submerged-arc techniques are employed, high energy inputs might readily be anticipated. Therefore, it seemed desirable to investigate the properties of the heat-affected zone of T-1 after exposure to the weld-thermal cycles resulting after preheats or high energy inputs, i.e., those involving slow cooling rates. The transformational behavior of T-1 upon continuous cooling also appeared to be of interest, since in this way it would be possible to correlate systematically cooling rates after welding with microstructure and with mechanical properties.

Object

The object of this program was to:

1. Determine the effect of weld-thermal cycles involving slow cooling rates upon the toughness of the heat-affected zone of T-1 steel.
2. Investigate the transformation characteristics of T-1 upon continuous cooling.
3. Correlate welding conditions and cooling rates with microstructure and mechanical properties.

Material

The material used in this investigation consisted of ½-in. plate of T-1

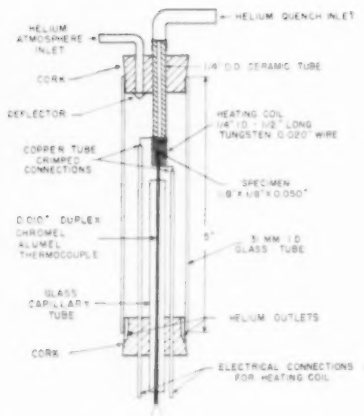


Fig. 1 Thermal analysis apparatus

steel. The chemical composition and mechanical properties of this material have been summarized below.

Check analysis, %:

C	0.15	Si	0.23	Cu	0.34
Mn	1.00	Ni	0.94	Mo	0.45
P	0.014	Cr	0.53	Sn	0.008
S	0.023	V	0.05	Ti	0.004
B	0.0014				

Mechanical properties:

Test location	*Yield strength, 0.2% offset, psi*	*Tensile strength, psi*
Long., bottom	114,500	122,400
Long., top	111,600	120,900
Trans., top	113,900	123,600

Elongation, % in 8 in.	*Elongation, % in 2 in.*	*Reduction in area, %*
13.1	27.0	54.3
10.7	25.0	52.8
11.5	29.0	50.1

Plate thickness 1/2 in.

Transition temperatures (as-received condition), Charpy keyhole impact (longitudinal specimen, notch perpendicular to rolled surface):

Ductility-transition temp. = −208° F (selected at center of scatter band; 12 ft-lb)

Fracture-transition temp = −110° F (selected at 50% shear level)

Hardness:

Rockwell C scale, 27.5

Brinell hardness no., 278 (3000-kg load)

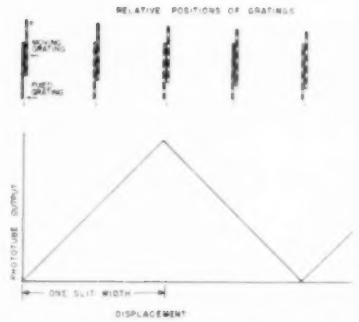


Fig. 2 Principle of the optical grating extensometer

Determination of Thermal Cycles

Previous data have been obtained[7,8] on the thermal cycles experienced by metal at various points in the heat-affected zone of a weld. To supplement these data and provide more extensive information, investigation was made of the thermal cycles experienced under conditions of high energy input and high travel speed.

Several welds were made with butt joints in 1/2-in. plate using a mechanized submerged-arc system. Welding was performed at approximately 675 amp, 40 v, ac, and 18 ipm travel speed, utilizing a 3/32-in. electrode. Plate preparation involved drilling holes 0.052 in. diam from the bottom of the plate to within 0.050 in. of the top surface. Chromel-alumel thermocouples, 0.010 in. diam, were then percussion welded to the bottom of these holes. Thermal

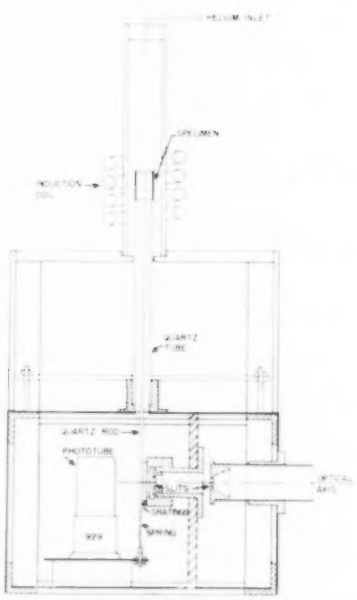


Fig. 3 Cross-sectional view of the high-speed dilatometric apparatus

cycles during welding at eight different distances from the weld centerline, ranging from 0.25 to 1.50 in., were recorded simultaneously on a multichannel galvanometer-type oscillograph. Arc current, voltage and power were recorded on recording meters. From the oscillograph traces of temperature vs. time, $F(s, d)$ values were calculated using the methods of Nippes, Merrill and Savage[7] and their expression

$$F(s, d) = \frac{(T - T_0)\,(1000)}{(\text{energy input})\,(\text{preheat factor})}$$

where

$F(s,d)$ = function of distance, d, from the weld centerline at time, s, after the arc passes.

T = temperature in ° F of a point in the heat-affected zone at distance, d, from the weld centerline at time, s.

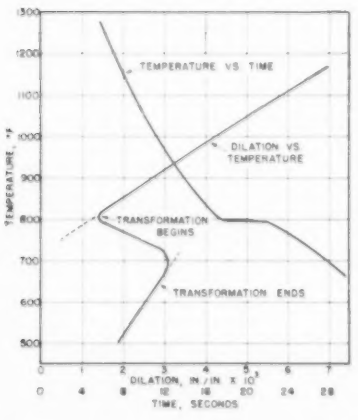


Fig. 4 Typical dilation curve, T-1 steel

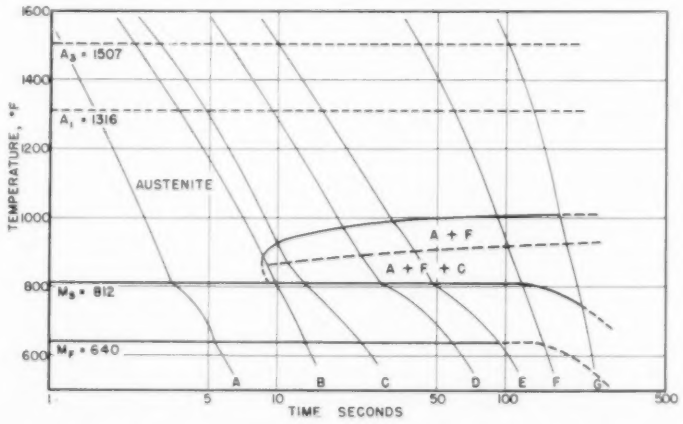


Fig. 5 Continuous-cooling transformation diagram T-1 steel, austenitized at 2000° F, grain size 7

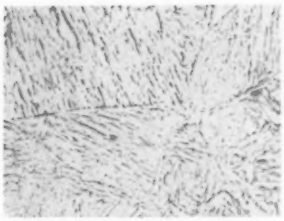


Fig. 6 Specimen A—picral etch, VPN 407. X1000. (Reduced by 50% upon reproduction)

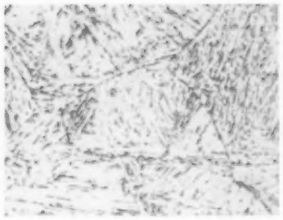


Fig. 7 Specimen B—picral etch, VPN 369. X1000. (Reduced by 50% upon reproduction)

Fig. 8 Specimen C—picral etch, VPN 359. X1000. (Reduced by 50% upon reproduction)

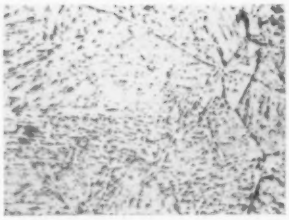


Fig. 9 Specimen D—picral etch, VPN 344. X1000. (Reduced by 50% upon reproduction)

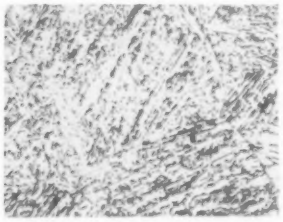


Fig. 10 Specimen E—picral etch, VPN 302. X1000. (Reduced by 50% upon reproduction)

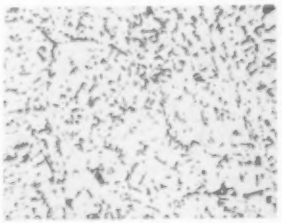


Fig. 11 Specimen F—picral etch, VPN 274. X1000. (Reduced by 50% upon reproduction)

Fig. 12 Specimen G—picral etch, VPN 256. X1000. (Reduced by 50% upon reproduction)

T_0 = initial plate temperature, ° F

energy input = weld energy input, joules/in.

preheat factor = multiplying factor to account for effect of preheat.

Determination of Continuous-Cooling Transformation Diagram

The transformation of T-1 steel upon continuous cooling was investigated by thermal evolution techniques. The apparatus used for the investigation is illustrated in Fig. 1. Specimens $^1/_8$- x $^1/_8$-x 0.050-in., machined from as-received T-1 plate, were austenitized for 15 sec at 2000° F by means of a tungsten resistance-heating coil. An inert atmosphere of helium or argon gas was used both for protection from oxidation and as a cooling medium. Various cooling rates were obtained by reducing the current through the heating coil at a controlled rate and by regulating the gas flow around the specimen. Experimental details of this apparatus have been described more fully in the literature.[9]

Temperature was measured by means of 0.010-in. diam chromel-alumel thermocouples percussion welded to the specimen. A high-speed oscillograph was employed to obtain a permanent record of the thermal cycle. Magnetically-damped galvanometers with a sensitivity of 863 mm/ma were used in this oscillograph.

Supplementary information on the transformation characteristics of T-1 was obtained through the application of high-speed dilatometry. Specimens consisted of hollow cylinders $^1/_2$ in. length, $^3/_8$ in. ID, and $^{13}/_{32}$ in. OD, machined from as-received T-1. To minimize oxidation upon heating, the cylinders were copper plated, using first a cyanide strike solution, followed by an acid sulfate plate.

Specimens were heated to 2000° F in a helium atmosphere by means of a high-frequency induction heating unit. Cooling rates after austenitization were controlled by regulating the rate of gas flow over the specimen. Temperatures were measured by 0.010-in. diam

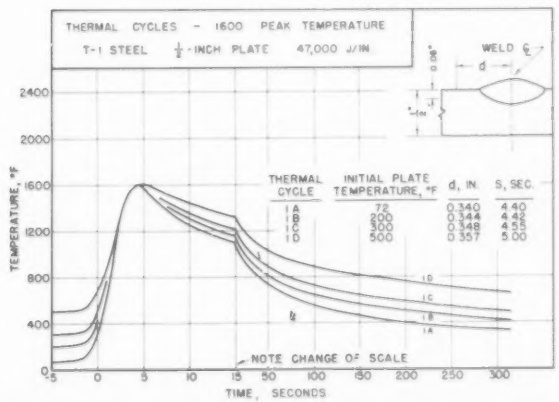


Fig. 13 Weld-thermal cycles—1600° F peak temperature, $^1/_2$-in. T-1 steel, 47,000 joules/in.

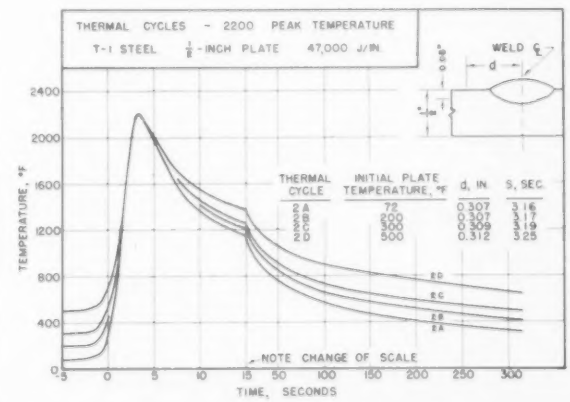


Fig. 14 Weld-thermal cycles—2200° F peak temperature, $^1/_2$-in. T-1 steel, 47,000 joules/in.

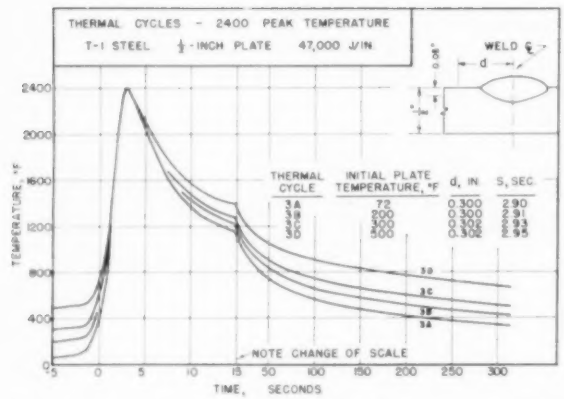


Fig. 15 Weld-thermal cycles—2400° F peak temperature, ½-in. T-1 steel, 47,000 joules/in.

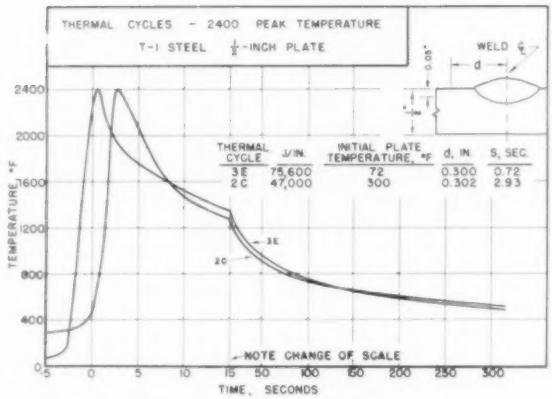


Fig. 16 Weld-thermal cycles—2400° F peak temperature, ½-in. T-1 steel, 47,000 joules/in.

chromel-alumel thermocouples percussion welded to the inner and outer surfaces of the cylindrical specimens. An oscillograph with galvanometer sensitivity of 750 mm/ma/m was used to record the output of the thermocouples.

Dilation was measured by use of an optical grating extensometer consisting of a stationary grating parallel to a movable grating attached to the specimen. Light from a source was transmitted through the gratings to a phototube. The variation in phototube output with specimen dilation was relayed by an amplifier circuit to the oscillograph. If the phototube output is plotted as a function of grating displacement, a cyclic form results, as indicated in Fig. 2. Each straight-line segment corresponds to the slit aperture.

Since the grating aperture (0.0025 in.) is less than the total contraction of the specimen, the dilation record will fold several times during the cycle. This folding multiplies the effective width of the oscillograph chart and thus makes possible a precision of ±3 microinches. A cross-sectional view of the high-speed dilatometer is given in Fig. 3. Further details of the experimental apparatus, developed previously at RPI, have been given in the literature.[10]

Values of dilation were read on the oscillograph trace and then plotted versus instantaneous temperature to give the typical dilation-temperature curve of Fig. 4. The beginning of a transformation occurs at the temperature at which the curve first deviates from linearity. Expansion of the specimen is indicated by a reversal of the curve. Upon completion of the transformation, the curve again becomes linear. The average coefficient of linear expansion in the austenitic range was found to be 15.1 x 10^{-6} in./in./F. This latter value is in reasonable agreement with that determined by other investigators.[2]

By austenitizing a large number of specimens and observing their thermal and dilation behavior upon cooling, the continuous-cooling transformation diagram, shown in Fig. 5, was determined for T-1. The values of Ae_3 and Ae_1 temperatures indicated are those calculated by the steel supplier's laboratories.[2] Microstructures corresponding to representative cooling rates are shown in Figs. 6–12. Hardness of the structures in Vickers Pyramid Numerals (VPN) is indicated beneath each photomicrograph.

Specimen A, illustrated in Fig. 6, represents cooling at a rate faster than the critical cooling rate and thus reveals a structure of 100% martensite. The hardness of the structure—VPN 407—is very close to that which would be anticipated for 100% martensite of this carbon content. Structure B, shown in Fig. 7, was cooled more slowly and shows the beginning of carbide precipitation and a tempering effect. This tendency is accentuated in specimen C, Fig. 8, and specimen D, Fig. 9; and hardness continues to decrease. In specimen E, Fig. 10., we observe the presence of fine pools of martensite and bainite, preferentially oriented in a matrix of super-saturated ferrite. Specimens F and G, Figs. 11 and 12, respectively, indicate a progressive decrease in the amount of low-temperature transformation products, with a consequent decrease in hardness.

Preparation and Testing of Simulated Specimens

Procedure

Utilizing the thermal-cycle data available, it was possible to prepare test specimens having the precise microstructure existing at any point in a weld heat-affected zone. For this in-

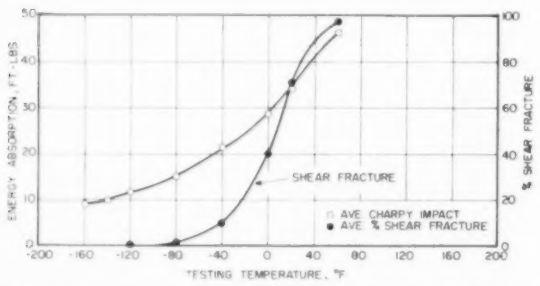


Fig. 17 Charpy vee-notch impact-temperature data for specimens produced by the thermal cycle with 1600° F peak temperature, 200° F initial plate temperature, 47,000 joules/in., ½-in. T-1 steel

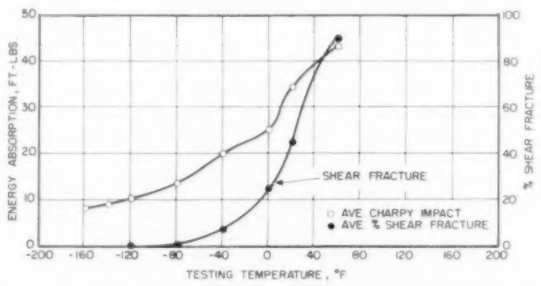


Fig. 18 Charpy vee-notch impact-temperature data for specimens produced by the thermal cycle with 1600° F peak temperature, 300° F initial plate temperature, 47,000 joules/in., ½-in. T-1 steel

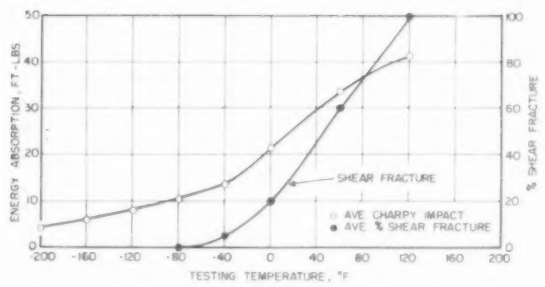


Fig. 19 Charpy vee-notch impact-temperature data for specimens produced by the thermal cycle with 1600° F peak temperature, 500° F initial plate temperature, 47,000 joules/in., $\frac{1}{2}$-in. T-1 steel

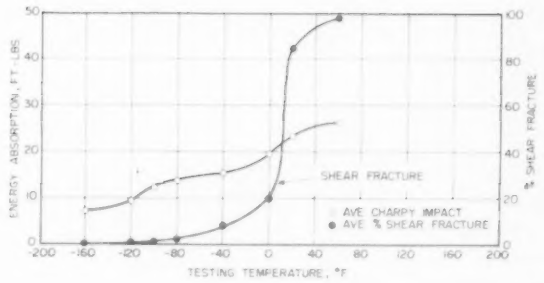


Fig. 20 Charpy vee-notch impact-temperature data for specimens produced by the thermal cycle with 2200° F peak temperature, 200° F initial plate temperature, 47,000 joules/in., $\frac{1}{2}$-in. T-1 steel

vestigation, specimens were prepared having microstructures corresponding to thermal cycles found in the heat-affected zone of $\frac{1}{2}$-in. plate under a variety of welding conditions. The effect of weld-thermal cycles in $\frac{1}{2}$-in. plate at 47,000 joules/in. energy input involving peak temperatures of 1600° F, 2200° F and 2400° F with initial plate temperatures of 200° F, 300° F and 500° F was studied. Previous data (Ref. 5) were already available on specimens heated to 1600° F, 2200° F and 2400° F with initial plate temperatures of 72° F and energy input of 47,000 joules/in.

Preliminary work indicated that the most deleterious effect on notch toughness occurred in material experiencing 2400° F peak temperatures. Furthermore, the thermal cycles in specimens welded at high energy inputs are very similar (at least in the cooling portion of the cycle) to thermal cycles with preheat at lower energy inputs. For this reason, to define the effect of high energy input on notch toughness, it was considered sufficient to examine one group of specimens after exposure to thermal cycles with peak temperature of 2400° F and energy input of 75,600 joules/in. The thermal cycles to which all specimens were exposed are shown graphically in Figs. 13–16.

Specimens for heat treatment were prepared from $\frac{1}{2}$-in. as-received plate stock of T-1 steel. Blanks 0.42- x 0.42- x 2.75-in. were machined so that the longitudinal axis of the blank was in the direction of rolling. A chromel-alumel thermocouple was percussion welded to the surface of the blank. The output signal from this thermocouple was balanced against the signal from a cam previously designed to reproduce the desired thermal cycle. The resultant error signal was utilized by the high-speed time-temperature controller developed in the Welding Laboratory of RPI to provide temperature control during the cycle of ±3° F. Specimens were clamped in water-cooled copper jaws during exposure to the thermal cycle. Details of the "simulated specimen" technique and the time-temperature controller have been described in the literature.[7, 10, 12]

Standard Charpy vee-notch specimens were prepared from the heat-treated blanks. The notch was oriented normal to the original plate surface. After a minimum aging time of 21 days at room temperature, the specimens were fractured in a Riehle 220 ft-lb impact-testing machine. In most cases a minimum of three specimens was tested at each testing temperature.

A liquid bath of 2-methyl butane, cooled with liquid nitrogen, was used to obtain specimen temperatures below −80° F. Temperatures of −80 to 32° F were obtained by means of a propyl alcohol bath cooled with dry ice, while water was used to obtain elevated testing temperatures. The temperatures of the testing solutions were measured with standard laboratory thermometers.

Results

Impact Data

Energy absorption prior to fracture and mode of failure were recorded for each specimen. Plots of energy absorption and percent shear fracture as a function of testing temperature are shown in Figs. 17–26. A similar plot for as-received T-1 is shown in Fig. 27 for comparison. The criterion for the ductility-transition temperature was chosen as the 10 ft-lb level. The temperature producing 50% shear failure was denoted as the fracture-transition temperature. A summary of thermal cycles and the resulting transition temperatures is given in Table 1.

Previous work[5] has shown that the welding of T-1 at an energy input of 47,000 joules/in. and an initial plate temperature of 72° F does not impair significantly the impact properties of the heat-affected zone. However, examination of Figs. 17–26 and Table 1 indicates a marked decrease in toughness with either increasing initial plate

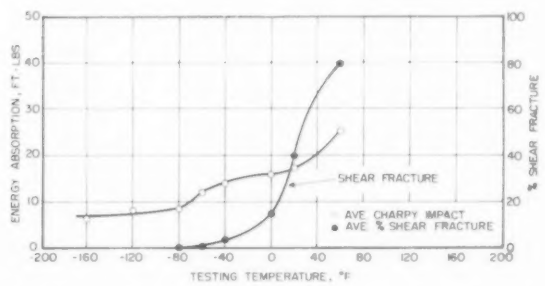


Fig. 21 Charpy vee-notch impact-temperature data for specimens produced by the thermal cycle with 2200° F peak temperature, 300° F initial plate temperature, 47,000 joules/in., $\frac{1}{2}$-in. T-1 steel

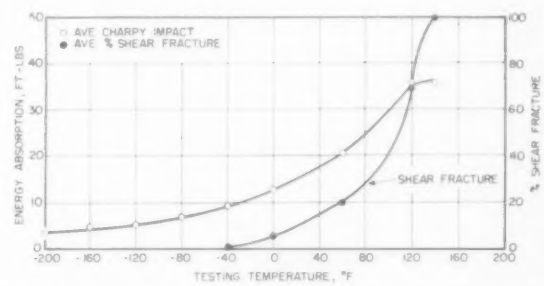


Fig. 22 Charpy vee-notch impact-temperature data for specimens produced by the thermal cycle with 2200° F peak temperature, 500° F initial plate temperature, 47,000 joules/in., $\frac{1}{2}$-in. T-1 steel

Table 1

Thermal cycle	Energy input, J/in.	Initial plate temperature, °F	Peak temperature, °F	Transition temperature, °F Ductility	Fracture
1A	47,000	72	1600	−140	0
1B	47,000	200	1600	−137	7
1C	47,000	300	1600	−126	23
1D	47,000	500	1600	− 87	46
2A	47,000	72	2200	−156	4
2B	47,000	200	2200	−115	12
2C	47,000	300	2200	− 71	26
2D	47,000	500	2200	− 28	111
3A	47,000	72	2400	−138	5
3B	47,000	200	2400	−100	25
3C	47,000	300	2400	− 47	68
3D	47,000	500	2400	26	152
3E	75,600	72	2400	− 16	71

temperature or increasing energy input. Figure 28 summarizes the effect of one of these variables, namely, initial plate temperature, on the ductility and fracture transitions of T-1 welded at 47,000 joules/in. and experiencing a thermal cycle with a 2400° F peak temperature. A 500° F preheat, for example, raises the ductility-transition temperature from −138 to +26° F, with a similar effect upon fracture-transition temperature. Increasing energy input is observed to have an analogous effect upon toughness.

Metallographic Examination

Microstructures of T-1 in the as-received condition and after exposure to each of the thermal cycles studied are shown in Figs. 29-42. Photomicrographs of T-1 exposed to similar thermal cycles with no preheat, previously studied by Nippes and Sibley[3] are also shown for comparison. All photomicrographs were taken at 1000 magnifications after picral etch.

The as-received specimen of Fig. 29 reveals a uniform structure of tempered martensite. Thermal cycling to 1600° F peak temperature resulted in incomplete austenitization, as indicated by the presence of a ghost structure. Uniform grain refinement is noted in the case of specimens exposed to 1600° F peak with no preheat (Fig. 30) or with 200° F preheat (Fig. 31). However, the slow cooling rates associated with 300° F (Fig. 32) and 500° F (Fig. 33) initial plate temperatures produce increasing amounts of ferrite patches in the microstructure.

Specimens of T-1 subjected to 2200° F peak temperature thermal cycles (Figs. 34–37) show grain refinement at low preheat temperatures, but grain growth at the higher preheat conditions. The structure of the specimen subjected to 2200° F peak temperature with no preheat is almost completely martensitic. However, increasing the initial plate temperature greatly increases the amount of ferrite and carbide precipitation.

Similar behavior is exhibited by specimens subjected to a peak temperature of 2400° F (Figs. 38–42). The martensite of the low-preheat specimens is gradually replaced by ferrite upon increasing the preheat. Thus, we see that, in the case of a 2400° F peak-temperature specimen with 500° F preheat, the structure comprises a predominantly ferritic matrix in which are imbedded pools of martensite and bainite. It should be emphasized that the ferrite precipitation upon cooling probably causes enrichment in carbon of the remaining austenite. Consequently, upon completion of the transformation, we actually observe high-carbon martensite or bainite in a matrix of supersaturated ferrite.

The thermal cycle for the specimen heated to 2400° F at high energy input (75,600 joules/in.) is very similar to the thermal cycle for the specimen heated to 2400° F at 47,000 joules/in. with 300° F preheat, as is shown in Fig. 16. We thus anticipate similar microstructures, as is indeed the case. This may be noted by comparison of Figs. 40 and 42.

To verify the validity of the synthetic thermal cycle treatment, metallographic examination was made of the heat-affected zone of several specimens of T-1 actually welded at 48,000 joules/in. with various initial plate temperatures. Illustrations of microstructures at regions corresponding to 2400° F peak temperatures in two of these specimens, welded with 300 and 500° F preheats, are shown in Figs. 43 and 44. It will be noted that the correlation between these structures and the microstructures of the corresponding synthetic specimens, Figs. 40 and 41, is excellent.

Discussion

The poor impact behavior in the heat-affected zone of specimens welded under conditions of high initial plate temperature or high energy input may readily be rationalized on the basis of microstructure. In the first place, it has been demonstrated that T-1 welded with no preheat and low-energy input retains good toughness in the heat-affected zone. This retention of toughness is directly attributable to the outstanding properties of low-carbon martensite. If in the extreme case the low-carbon martensite is replaced by a structure consisting of an aggregate of ferrite and high-carbon martensite, the latter a notably brittle constituent, the

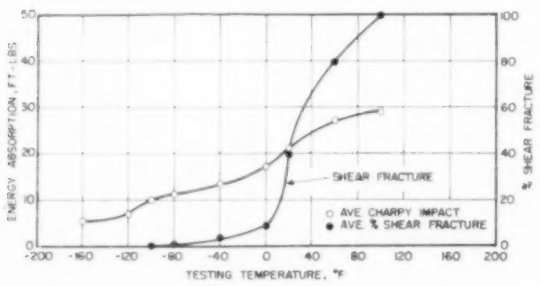


Fig. 23 Charpy vee-notch impact-temperature data for specimens produced by the thermal cycle with 2400° F peak temperature, 200° F initial plate temperature, 47,000 joules/in., ½-in. T-1 steel

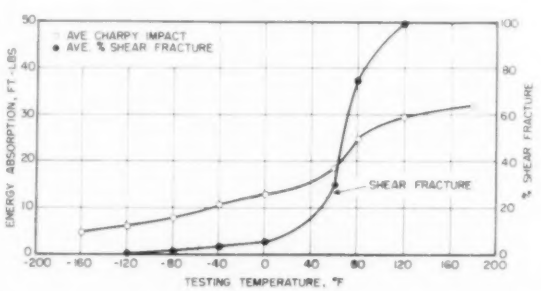


Fig. 24 Charpy vee-notch impact-temperature data for specimens produced by the thermal cycle with 2400° F peak temperature, 300° F initial plate temperature, 47,000 joules/in., ½-in. T-1 steel

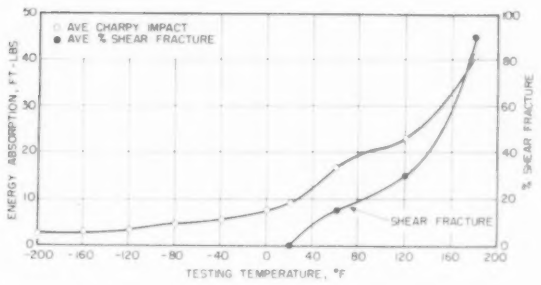


Fig. 25 Charpy vee-notch impact-temperature data for specimens produced by the thermal cycle with 2400° F peak temperature, 500° F initial plate temperature, 47,000 joules/in., 1 in. T-1 steel

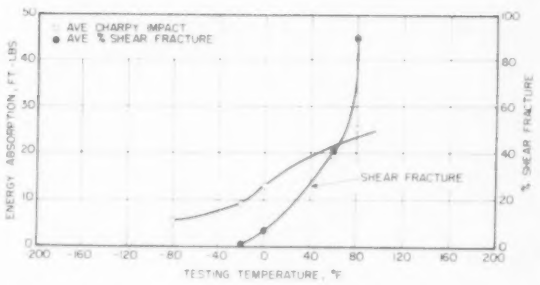


Fig. 26 Charpy vee-notch impact-temperature data for specimens produced by the thermal cycle with 2400° F peak temperature, 72° F initial plate temperature, 75,600 joules/in., 1 in. T-1 steel

toughness of the material will obviously be destroyed. Unfortunately, the martensite pools in the ferrite matrix were too small to permit microhardness measurements that would have afforded quantitative measure of the extent of carbon enrichment of the austenite prior to transformation to martensite. Some substantiation for the hypothesis of austenite enrichment is provided by the fact that the Ms temperature is depressed at slow cooling rates, i.e., at cooling rates that produce considerable proeutectoid ferrite and hence might be suspected to cause a significant amount of carbon enrichment of untransformed austenite. However, recent work by Blickwede and Hess[13] indicates that stabilization of the austenite-martensite reaction may occur as an independent phenomenon at slow cooling rates. The slightly-increased grain size resulting from the slower cooling rates would, if anything, tend to raise the Ms temperature.

Other factors may also explain the loss in toughness with decreasing cooling rates. Thus, the mere fact that strength is diminished by slow cooling with no concomitant increase in ductility undoubtedly has some deleterious effect. Of even more importance, however, is the inherent inferiority in toughness of mixed or slack-quenched structures. This structural notch effect has been demonstrated upon numerous occasions in the past.[14–16]

It was considered advisable to establish some single parameter which would permit prediction of impact performance, rather than relate toughness to both initial plate temperature and energy input. Toughness is, of course, highly structure-sensitive. Therefore, since microstructure, cooling rate, initial plate temperature, and energy input are so closely inter-related, it was felt that impact performance could be satisfactorily equated to cooling rate. Examination of the continuous-cooling transformation diagram suggested that the cooling rate at 900° F would probably be the most sensitive index to microstructure and hence to toughness. The transition temperatures as a function of cooling rate at 900° F for 1 in. plate experiencing thermal cycles with peak temperatures of 2400° F are shown in Fig. 45. A similar correlation exists for T-1 exposed to thermal cycles with peak temperatures of 2200 and 1600° F. However, since toughness is a minimum for material subjected to thermal cycles with 2400° F peak temperature, the correlation for other thermal cycles has not been shown.

As a criterion for the specification of welding conditions which produce resistance to brittle failure, the ability of the material to absorb at least 10 ft-lb of energy at −50° F was selected. With this criterion as a basis, it is seen from Fig. 46 that a minimum cooling rate of 6.5 F sec is required. From previous work[3] and from data obtained in this investigation, it is possible to predict the welding conditions which will produce cooling rates of this value. These conditions are summarized graphically in Figs. 47–48. Since notch toughness

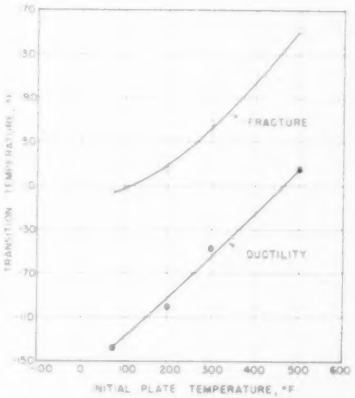


Fig. 28 Ductility transition and fracture transition temperatures vs. initial plate temperature, 1 in. T-1 steel, 47,000 joules/in. 2400° F peak temperature

is a function of microstructure, it has been possible to define welding conditions that produce cooling rates of 6.5° F sec in plate thicknesses other than 1 in. The relationship between a thermal cycle experiencing a cooling rate of 6.5° F sec at 900° F and the thermal cycles studied in this investigation is shown on a continuous-cooling transformation diagram in Fig. 49.

As plate thickness increases, heat is extracted from the weld more rapidly. Thus, for a given set of welding conditions, cooling rates are more rapid in

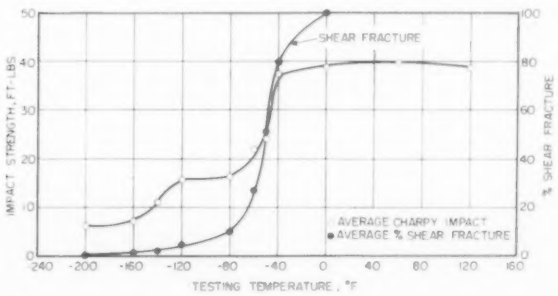


Fig. 27 Charpy vee-notch impact-temperature data, as-received 1 in. T-1 steel

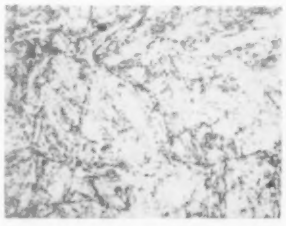


Fig. 29 As-received T-1—picral etch, VPN 294, X1000. (Reduced by 50% upon reproduction)

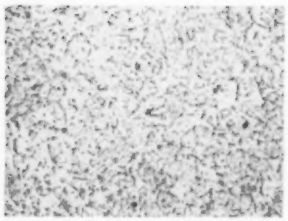


Fig. 30 Synthetic specimen —1600° F peak temperature, 72° F initial plate temperature, 47,000 joules/in., picral etch, VPN 334. X1000. (Reduced by 50% upon reproduction)

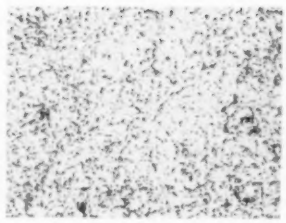


Fig. 31 Synthetic specimen —1600° F peak temperature, 200° F initial plate temperature, 47,000 joules/in., picral etch, VPN 302. X1000. (Reduced by 50% upon reproduction)

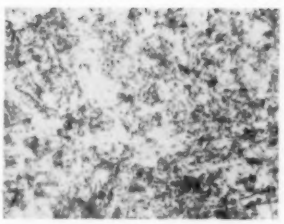


Fig. 32 Synthetic specimen —1600° F peak temperature, 300° F initial plate temperature, 47,000 joules/in., picral etch, VPN 294. X1000. (Reduced by 50% upon reproduction)

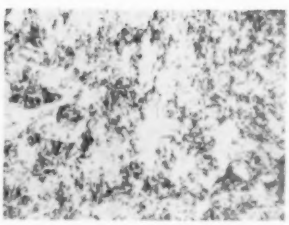


Fig. 33 Synthetic specimen —1600° F peak temperature, 500° F initial plate temperature, 47,000 joules/in., picral etch, VPN 277. X1000. (Reduced by 50% upon reproduction)

thick plate. In other words, although for 1-in. plate with a preheat of 300° F the maximum energy input is 24,500 joules/in., in welding 1-in. plate with 300° F preheat an energy input of 126,000 joules/in. may be sustained.

As shown in Fig. 47, welding at high travel speeds with submerged-arc techniques reduces cooling rates as compared to manual-arc techniques at low travel speeds. That is, welding with submerged-arc techniques necessitates a reduction in either initial plate temperature or energy input to produce the same microstructure in the heat-affected zone. The slower cooling rates associated with submerged-arc welding are primarily attributable to the larger weld beads produced at higher travel speeds.

Since pressure-vessel steels occasionally fail by shear at more elevated temperatures, it is of interest to examine the effect of variations in cooling rate upon impact properties under these conditions. Energy absorption at 80° F as a function of cooling rate necessary to produce energy absorption of 10 ft-lb at −50° F (6.5° F/sec) results in energy absorption of 25.8 ft-lb at 80° F, as shown in Fig. 46.

It is important to emphasize that the data of Figs. 47–48 present only the manifestations of the metallurgical variable. There are, consequently, several limitations to the use of these data in predicting actual service performance. In the first place, although it is true that a cooling rate of 6.5° F/sec will produce similar microstructures in any size plate (and hence similar impact performance as measured in a Charpy test), performance under service conditions will not necessarily be identical. Because of the greater notch restraint, brittle failure will be more probable in the thick plate.

In the second place, a low notch toughness in the heat-affected zone does not necessarily entail that failure will be either initiated or propagated in this region in an actual fabricated structure. In addition to examining the metallurgical state, the residual-stress pattern after welding must also be taken into consideration. If defects or residual tensile stresses exist in some other portion of the weldment, the inferior microstructure of the heat-affected zone may be but a minor factor in the performance of the structure as a whole.

Summary and Conclusions

1. Thermal cycles experienced in the heat-affected zone of T-1 steel welded under conditions of high energy input were measured by oscillographic techniques.

2. The continuous-cooling transformation behavior of T-1 steel was determined by thermal analysis and by high-speed dilatometry.

3. Synthetic specimens were prepared to simulate the structure at several points in the heat-affected zone under a variety of welding conditions. The impact performance and hardness of these specimens were determined and were correlated with microstructure. Microstructures of the synthetic specimens were checked against the microstructures of actual weld specimens to verify the validity of the synthetic-specimen technique.

4. Slow cooling rates after welding, such as may result from either high energy input or high initial plate temperature, have a damaging effect upon the notch toughness in the heat-affected zone of T-1 steel.

5. The loss in notch toughness of the heat-affected zone after slow cooling is caused by the presence of a microstructure consisting of martensite and bainite in a matrix of ferrite.

6. A minimum cooling rate of 6.5° F/sec at 900° F after welding is required to produce satisfactory notch toughness, as defined by the ability to absorb 10 ft-lb of energy at −50° F. The weld-energy input and initial plate temperatures that produce this cooling rate were calculated for various plate thicknesses.

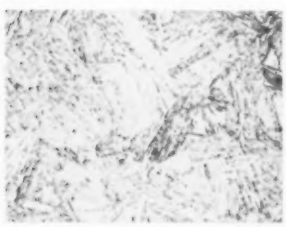


Fig. 34 Synthetic specimen —2200° F peak temperature, 47,000 joules/in., picral etch, VPN 394. X1000. (Reduced by 50% upon reproduction)

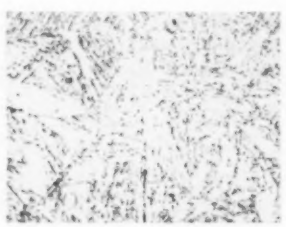


Fig. 35 Synthetic specimen —2200° F peak temperature, 200° F initial plate temperature, 47,000 joules/in., picral etch, VPN 375. X1000. (Reduced by 50% upon reproduction)

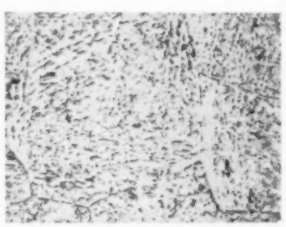


Fig. 36 Synthetic specimen —2200° F peak temperature, 300° F initial plate temperature, 47,000 joules/in., picral etch, VPN 325. X1000. (Reduced by 50% upon reproduction)

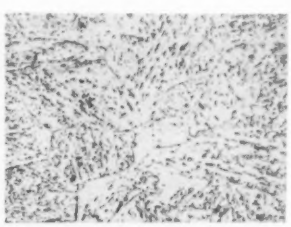


Fig. 37 Synthetic specimen —2200° F peak temperature, 500° F initial plate temperature, 47,000 joules/in., picral etch, VPN 307. X1000. (Reduced by 50% upon reproduction)

Fig. 38 Synthetic specimen —2400° F peak temperature, 72° F initial plate temperature, 47,000 joules/in., picral etch, VPN 393. X1000. (Reduced by 50% upon reproduction)

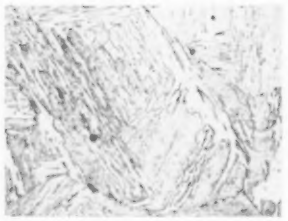


Fig. 39 Synthetic specimen —2400° F peak temperature, 200° F initial plate temperature, 47,000 joules/in., picral etch, VPN 379. X1000. (Reduced by 50% upon reproduction)

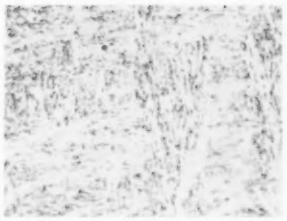


Fig. 40 Synthetic specimen —2400° F peak temperature, 300° F initial plate temperature, 47,000 joules/in., picral etch, VPN 336. X.1000 (Reduced by 50% upon reproduction)

Fig. 41 Synthetic specimen —2400° F peak temperature, 500° F initial plate temperature, 47,000 joules/in., picral etch, VPN 321. X1000. (Reduced by 50% upon reproduction)

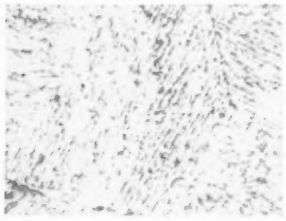


Fig. 42 Synthetic specimen —2400° F peak temperature, 72° F initial plate temperature, 75,600 joules/in., picral etch, VPN 329. X1000. (Reduced by 50% upon reproduction)

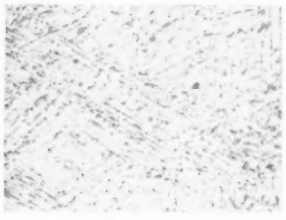


Fig. 43 Section of specimen welded at 48,000 joules/in., peak temperature 2400° F, initial plate temperature 300° F, picral etch, VPN 342. X1000. (Reduced by 50% upon reproduction)

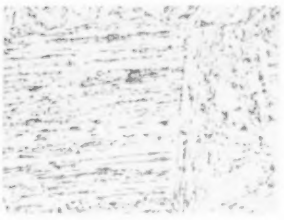


Fig. 44 Section of specimen welded at 48,000 joules/in., peak temperature 2400° F, initial plate temperature 500° F, picral etch, VPN 318. X1000. (Reduced by 50% upon reproduction)

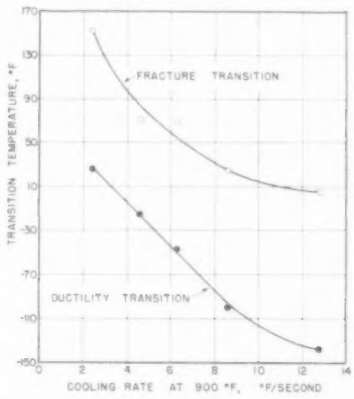


Fig. 45 Ductility and fracture transition temperatures vs. cooling rate at 900° F, 1½-in. T-1 steel

Acknowledgments

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References

1. Bibber, L. C., Hodge, J. M., Altman, R. C., and Doty, W. D., "A New High-Yield Strength Alloy Steel for Welded Structures," *Trans. ASME*, **74** (3), 269–285 (1952).

2. Doty, W. D., "Properties and Characteristics of a Quenched and Tempered Steel for Pressure Vessels," THE WELDING JOURNAL, **34** (9), Research Suppl., 425-s to 441-s (1955).

3. Zick, L. P., "Design of Welded Pressure Vessels Using Quenched and Tempered Steels," *Ibid.*, **34** (9), Research Suppl., 442-s to 448-s (1955).

4. Bibber, L. C., "Suitability of Quenched and Tempered Steel for Welded Pressure-Vessel Construction," *Ibid.*, **34** (9), Research Suppl., 449-s to 463-s (1955).

5. Nippes, E. F., and Sibley, C. R., "Impact Performance of Synthetically Reproduced Heat-Affected-Zone Microstructures in T-1 Steel," *Ibid.*, **35** (10), Research Suppl., 473-s to 479-s (1956).

6. Aborn, R. H., "Low-Carbon Martensites," *Trans. Am. Soc. Metals*, **48**, 51–85 (1956).

7. Nippes, E. F., Merrill, L. L., and Savage,

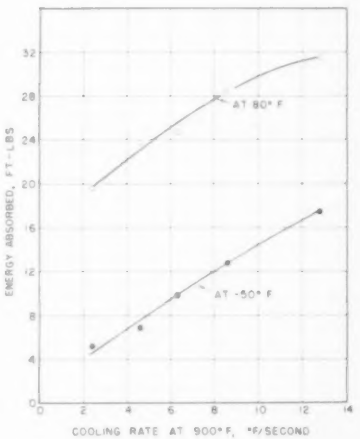


Fig. 46 Energy absorbed in ft-lb vs. cooling rate at 900° F, 1½-in. T-1 steel

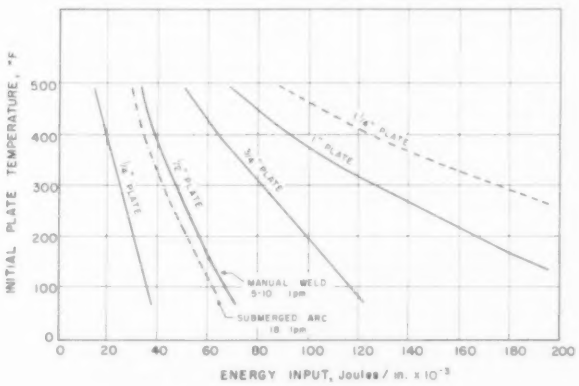


Fig. 47 Summary of welding conditions which produce cooling rate at 900° F of 6.5° F/sec, T-1 steel

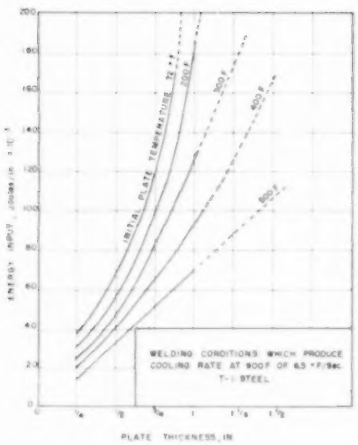

INITIAL PLATE TEMPERATURE, 70 °F
200 F
300 F
400 F
500 F
WELDING CONDITIONS WHICH PRODUCE COOLING RATE AT 900 F OF 6.5 °F/Sec. T-1 STEEL
PLATE THICKNESS, IN.

Fig. 48 Summary of welding conditions which produce cooling rate at 900° F of 6.5° F/sec, T-1 steel

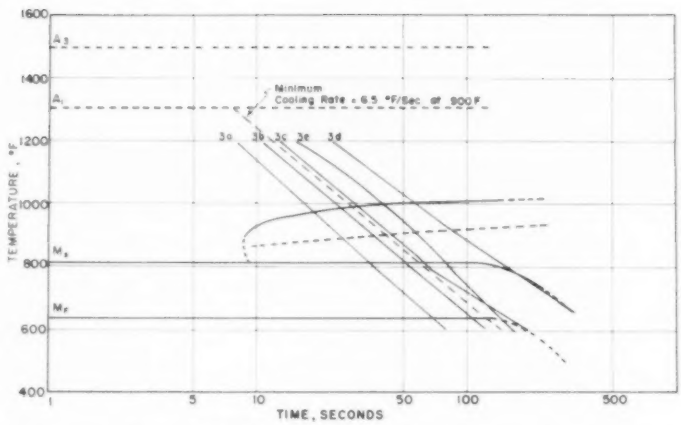


Fig. 49 Actual weld-thermal cycles indicated on continuous-cooling transformation diagram, T-1 steel

W. F., "Cooling Rates in Arc Welds in ½-in. Plate." The Welding Journal, **28** (11), Research Suppl., 556-s to 564-s (1949).

8. Hess, W. F., Merrill, L. L., Nippes, E. F., and Bunk, A. P., "The Measurement of Cooling Rates Associated with Arc Welding and Their Application to the Selection of Optimum Welding Conditions." *Ibid.*, **8** (9), Research Suppl., 377-s to 422-s (1943).

9. Nippes, E. F., Gerken, J. M., Schaaf, R. W., and Nelson, E. C., "Thermal Cycles in the Arc Welding of ½-in. Titanium Plate." *Ibid.*, **18** (9), Research Suppl., 461-s to 474-s (1953).

10. Nelson, E. C., "A High-Speed Dilatometer Designed for Welding Research," to be published in January 1958 issue of The Welding Journal, Research Suppl.

11. Nippes, E. F., and Savage, W. F., "Tests of Specimens Simulating Weld Heat-Affected Zones." *Ibid.*, **28** (12), Research Suppl., 599-s to 616-s (1949).

12. Nippes, E. F., and Savage, W. F., "Development of Specimen Simulating Weld Heat-Affected Zones." *Ibid.*, **28** (11), Research Suppl., 534-s to 546-s (1949).

13. Blickwede, D. J., and Hess, R. C., "On the Cooling Transformations in Some 0.40% Carbon Constructional Alloy Steels." *Trans. Am. Soc. Metals*, **49**, Preprint No. 17 (1956).

14. Holloman, J. H., Jaffee, L. D., McCarthy, D. E., and Norton, M. R., "The Effects of Microstructure on the Mechanical Properties of Steel." *Trans. Am. Soc. Metals*, **38**, 807–847 (1947).

15. French, Herbert J., "Some Aspects of Hardenable Alloy Steels." Howe Memorial Lecture (1956).

16. Lodge, J. W., and Manning, G. K., "The Mechanical Properties of Quenched and Tempered Medium-Carbon Alloy Steels." Contributions to the Metallurgy of Steel—No. 49, American Iron and Steel Institute, October 1954.

Correction:

"Ductility of Tungsten-Arc Welds in Molybdenum"

By N. E. Weare, R. E. Monroe and D. C. Martin

In the June 1957 issue of The Welding Journal, *Research Supplement, page 293-s, no captions are given for Figs. 3c and 3d. These captions should read as follows:*

c. Leading Shield *d. Dragging Shield*

Also, the following acknowledgment should be made a part of this paper:

"Work performed under AEC Contract W-7405-eng-92"

The Editors

SELECTION OF WELDING-ROD CHEMICAL COMPOSITION THROUGH MATHEMATICS

BY G. H. BOHN

A procedure for determining the most satisfactory chemical composition for the copper-silicon-manganese-iron alloy welding rod is proposed by author

SYNOPSIS. This paper presents the procedure that was used for determining the most satisfactory chemical composition for the copper-silicon-manganese-iron alloy welding rod. A mathematical formula was developed to determine the minimum resultant tensile strength of the weld as a function of the silicon, manganese and iron contents. The desired fluidity of the weld pool, to eliminate weld cracking, was obtained by maintaining the ratio of silicon to manganese to an experimentally determined minimum.

Finally, as a result of the data presented, it is suggested that certain slight revisions be made in the chemical composition in present specifications[1] for the copper-silicon welding rod.

Introduction

Interest has been indicated in the method used for arriving at a satisfactory chemical composition for the copper-silicon welding rod in present specifications.[1] Therefore, it is the intent of this paper to present this method as a guide to others as a possible solution to their particular welding rod problems.

Over the past 20 years, there has been the problem of weldability and tensile strength of the copper-silicon-manganese-iron alloy for welded ASME Code vessels. Newer alloys such as aluminum and stainless steels, have in recent years, also entered the picture. Nevertheless, this paper's discussion is confined to the copper-silicon alloy because the test data available is limited to this alloy.

Early investigations on new alloys center mostly around welding procedures. Good welding practice is always a must but, as in the copper-silicon alloy case, difficulties can still be encountered. It was when more attention was turned to the chemical analysis of the welding rod that difficulties were gradually eliminated.

Three important factors must be controlled in the welding rod to obtain satisfactory welded joints: (1) a minimum ultimate tensile strength of the weld metal, (2) optimum fluidity of the weld pool, (3) a limit on the iron and silicon contents. These are treated separately in the following discussion, but are of necessity one over-all problem.

G. H. Bohn is Design and Metallurgical Engineer, Linde Co., Division of Union Carbide Corp., Tonawanda, N. Y.

Abbreviations

Certain abbreviations will generally be used in the following discussion. These are:

Full Term	*Abbreviation*
Copper-silicon-manganese-iron	Copper-silicon
Silicon	Si
Manganese	Mn
Iron	Fe
Mathematical formula	"Formula"
Chemical analysis	Analysis
Ultimate tensile strength	Tensile strength
Ratio of silicon/manganese	"Ratio"

The Mathematical Formula for Tensile Strength

It has been shown in an ASTM paper[2] that the tensile strength of the copper-silicon alloy, whether base metal or weld metal, obeys the mathematical formula:

$$\text{Tensile strength} = K_1 + K_2\alpha$$

where

$$\alpha = \%\text{Si} + (\%\text{Fe} \times 1.25) - (\%\text{Mn} \times 0.25)$$

K_1 and K_2 are constants determined by plotting weld tensile-strength test results as ordinate versus α of the analysis as the abscissa. The result is a straight line (or a band of points with maximum and minimum limits). The constants K_1 and K_2 are then calculated by selecting two points on opposite ends of the line from which values for tensile strength and α are known. Substituting these values in the formula, two algebraic equations result from which K_1 and K_2 can be calculated. K_1 and K_2 are constants[2] for a particular welding procedure, being different for each welding procedure.

The following section on the use of this "formula" will be restricted to the tensile strength of the weld metal as a function of α.

In order to plot the tensile strength of the weld versus α of the weld, it is first necessary to convert the analysis by arithmetic into a single α figure. Fortunately, test data have proved that the analysis of the welding rod and the analysis of the final all-weld metal of fillet welds, or in the middle of the thick-plate welds, are for all practical purposes the same. Some typical cases are shown in Tables 1 and 8.

Table 1—Comparison of Oxyacetylene Weld and Rod Analysis

Heat no.	*Rod or weld*	*Analysis, %* Si	Fe	Mn	α
Sample 1	Weld*	3.05	0.10	1.20	2.87
	Rod	2.99	0.10	1.24	2.80
Sample 2	Weld*	3.20	0.10	0.98	3.08
	Rod	3.14	0.10	1.02	3.01
Sample 3	Weld*	2.99	unknown	0.94	...
	Rod	3.00	0.05	0.97	2.82
257	Weld*	3.41	0.17	0.51	2.50
	Rod	3.38	0.19	0.48	2.50

* In middle of oxyacetylene weld of 7/8-in. thick plate.

Test data[2] also showed that the analyses of the billet (from which the rod is made) may or may not be the same as the rod. After this became known, the analyses of special heats were made from the rods and not the billets. When a reported analysis of any heat showed an analysis worthy of test work, the rods actually used in the welding tests were analyzed. In cases where the heat number of the billet was known, that number was used to identify the billet and or the rod analysis. In some cases where the billet heat number of the rod was not known, the Laboratory analysis number was used to identify the rod analysis.

The test data in Tables 1 and 8 and tests showed that α of the rod can be used instead of the α of the weld when plotting the test results.

For any welding processes, it has been definitely proved[2] that for $^3/_8$-in. plate thickness, the center weld analysis is a blending of the plate and rod analysis. It also has been proved that this blending varies with each welder. For carbon-arc or inert-arc welding, $^1/_2$ in. was the minimum thickness that could be used to have the center weld analysis the same as the rod analysis. For oxyacetylene welding, $^3/_4$ in. was the minimum thickness that could be used to prevent blending. With these limitations set, test results could be plotted as tensile strength of the weld versus α of the rod.

If tensile-strength values for correctly made tests are plotted versus α of the welding rod, the result is a band of points. Three lines can be drawn, an upper line as the maximum, a lower line as the minimum, and one-half way as the average. This is the method used for Fig. 1. In the early days in the use of this alloy, there was only oxyacetylene and carbon-arc welding; so, quite a bit of test data were collected on these two processes. These test data are shown plotted for oxyacetylene welds as Fig. 1 and for carbon-arc welds as Fig. 2. Some values for gas tungsten-arc (inert-arc) welds are shown in Fig. 2—indications are that the tensile strengths are higher than for carbon-arc.

In both cases, α is generally based on the composition of the welding rod. When α based on the analysis of billet did not cause the points to lie inside of the maximum and minimum lines, an analysis was made on the rod used. Every time the new α would bring the points inside of the band.

In Fig. 1, a small circle for the test value indicates that the test specimen was an all-weld 0.505-in. round tensile specimen; a small square for the test value indicates that the test specimen was a reduced-section tensile specimen taken from $^7/_8$-in. thick plate with fracture in the center of the weld.

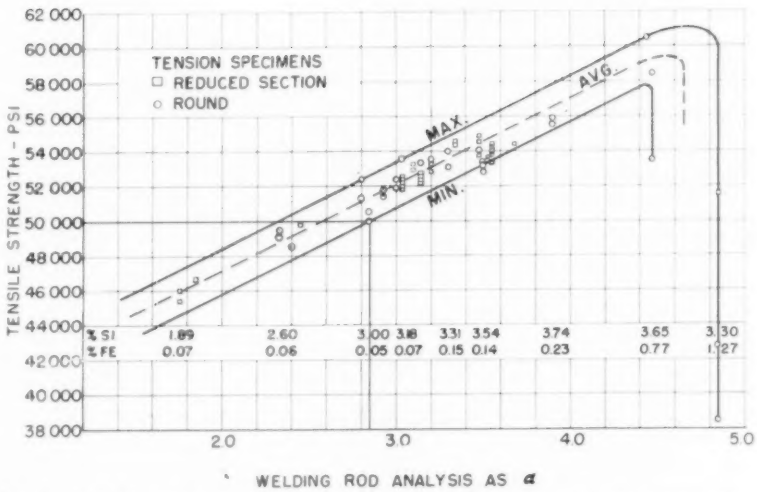


Fig. 1 Tensile strength versus chemical analysis for copper-silicon oxyacetylene weld metal

In Fig. 2, similarly, the symbols have the same connotation except that the reduced-section specimens were taken from $^3/_4$- or $^1/_2$-in. thick plate.

It is to be noted that the test values for both types of test specimens check each other in Figs. 1 and 2.

The ASME Code[3] requires a minimum welded tensile strength of 50,000 psi whether fracture is the weld or base metal. The tensile strength as plotted in Figs. 1 and 2 determines what the analysis of the welding rod should be by means of α. For instance these figures show a horizontal line starting from the ordinate at 50,000 psi and intersecting the lower limit of the band, then vertically down to the abscissa.

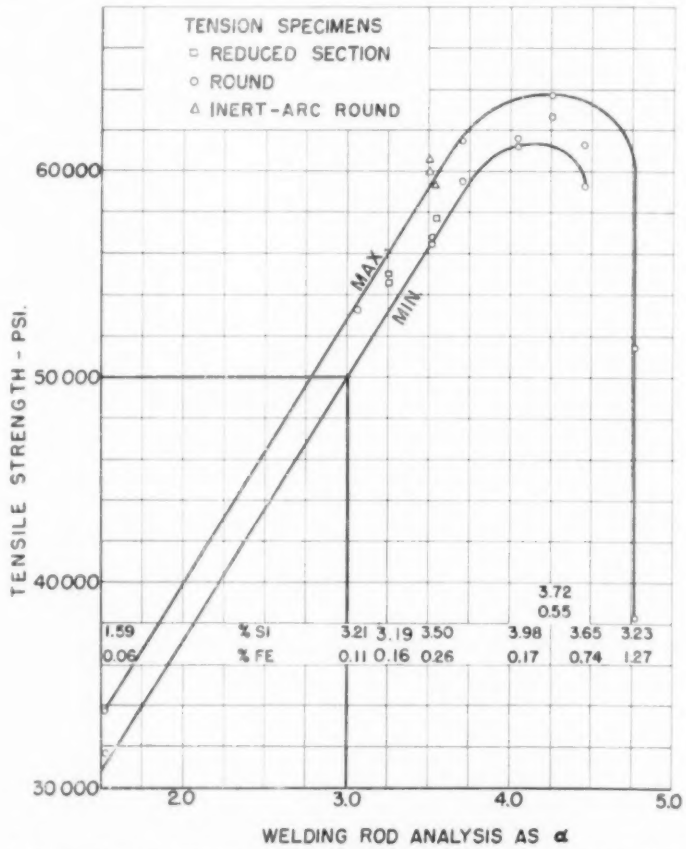


Fig. 2 Tensile strength versus chemical analysis for copper-silicon carbon-arc weld metal

Table 2—Preliminary Test Data

Test plate no.	Chemical analysis, % Cu	Si	Fe	Mn	α	Ratio, Si/Mn	Fluidity	Average* tensile strength, psi
AB-3	95.75	3.24	0.10	0.81	3.17	4.00	Good, best of four plates	55,200
AB-4	96.10	2.84	0.11	0.89	2.76	3.19	Melted freely	50,700
AB-1	95.10	3.54	0.10	1.22	3.36	2.91	Just OK, but not as good as AB-3 and AB-4	57,800
AB-2	95.66	3.05	0.08	1.19	2.85	2.69	Viscous, like sand	51,300
AB-5	94.50	4.09	0.11	1.28		3.20	Could not weld	

* All fractures in base metal of welded plate.

This determines the minimum required α of the welding-rod analysis to produce a minimum tensile strength of 50,000 psi for the weld metal. According to these test data, the following are the required α to meet ASME Code requirements:

Figure no.	Condition	Min. α for rod
1	Oxyacetylene weld	2.82
2	Carbon-arc weld	3.00

There is not enough test data available to accurately determine the minimum α for inert-arc weld but test results on welder's qualification indicate that the tensile strength is probably higher than for oxyacetylene or carbon-arc weld for the same analysis. This is substantiated in Fig. 2.

Knowing the required minimum α for the weld metal, the analysis of the welding rod cannot have an α less than given above to be able to pass the minimum tensile strength required by ASME Code welding-procedure qualification[3] where reduced-section tension-test specimens with no weld reinforcement are required. The same will also apply to pressure vessels when the weld is ground flush. This, therefore, determines α of the rod even though the pressure vessel seams may have weld reinforcement and are stronger than flush welds. There are other weldability factors that combined with α will determine the complete analysis range for the rod.

The "formula" does indicate that for higher tensile strength, the Si should be higher and the Mn lower. Fortunately, when this is done, weldability according to the following discussion is better.

Fluidity Versus the Ratio of Silicon/Manganese

It is stated in the AWS Welding Handbook[4] that the chemical composition and high fluidity, when molten, of copper alloys have a considerable bearing on their weldability. This is particularly true of the copper-silicon alloy. Weldability is defined by the AWS[5] as "the capacity of a metal to be welded under the fabrication conditions imposed into a specific, suitable, designed structure and to perform satisfactorily in the intended service."

Weldability or fluidity in the copper-silicon alloy are practically the same. When both base metal and welding rod flow freely, weldability is excellent. With poor fluidity, welds have a tendency to crack. It will be shown that fluidity is a function of the Si/Mn ratio of plate and/or rod. This section will therefore include test data on both welding rod and plate analysis and the final conclusion translated into welding-rod analysis.

Prior to 1935, it was noted that some welding rods and some base metal plates melted freely and a great many others were viscous during welding. What caused this was not known. Therefore, in 1935 five $\frac{3}{8}$-in. thick plates were processed by the mill in exactly the same manner, except for varying Si and Mn contents and approximately a constant Fe content. These were purposely made as follows:

Heat	Silicon	Manganese
AB1	High	High, approx. 1.20%
AB2	Low	High, approx. 1.20%
AB3	High	Low, approx. 0.80%
AB4	Low	Low, approx. 0.80%
AB5	Extra high	High

These were welded with exactly the same procedure and with the same welding rod. A record was made on the welder's reaction concerning the fluidity of these five test plates. Table 2 gives the test results with the plates arranged in order of best fluidity. Only the fluidity test results on plates AB1-4 incl. in Table 2 will be discussed now. Plate AB5 could not be welded and the reason is explained in the section entitled "Effect of High Silicon." Comparing the values for Si, Fe, Mn and tensile strengths in order of best weld fluidity, it is to be noted that none of these seemed to have a bearing on fluidity except perhaps low Mn. However, it is to be noted that the higher the "ratio" of Si/Mn, the better the fluidity.

In the following discussion the term "ratio" is intended to mean the "ratio" of Si/Mn in the analysis of rod or plate. With the "ratio" as the first clue to fluidity, the welding shop was instructed that whenever a particularly high- or low-fluidity rod or plate was noticed to advise the heat number or if unknown to save a sample.

Late in 1935, welders reported that a $\frac{3}{8}$-in. thick plate flowed freely under the torch and was ideal for welding. A tensile test showed that the ultimate tensile strength of the welded plate with fracture in the plate was 4 5000 psi over the required 50,000-psi minimum. A piece of the plate was therefore analyzed with the following results: silicon, 3.29% and manganese, 0.90%. This results in a "ratio" of 3.29/0.90 or 3.65. Table 2 test results showed that, with a "ratio" between 4.00 and 3.19, the fluidity was good; so, this checked the preliminary test data.

To help in this research, the mill was instructed to make an analysis of each heat of welding rod, to place only the rod from one heat in each box, and to stencil the heat number on each box. The analyses of special heats were made on the rod instead of the billet. In both cases, the heat number of the billet was used to identify the rod analysis.

It was soon discovered that the practical aspect of high fluidity was that the higher the "ratio," the better the fusion of the weld into plate. This can noticeably be seen on single vee-groove welds for any type of welding, whether oxyacetylene, carbon-arc or inert-arc welding. On oxyacetylene welding, it is possible with the welder's glasses to note the difference in fluidity of the plate and rod during the welding operation. On the other two types of welding, this can be best noticed after the welding is completed by looking at the back side of the weld. It is possible with high "ratios," but not low "ratios," to weld an entire single vee-groove weld and not have to chip out and back-weld to insure full fusion. All that is necessary is to remelt the weld protrusions on the back side of the weld. This certainly is a most desirable welding feature.

Based on varying analyses of approximately 1400 known compositions of welding rods and a large number of

plates from 1935 to date, it was determined that:

With welding rod "ratios" of under 2.00 the first weld bead in plates will crack due to hot shortness. A typical case was a $^1/_4$-in. diam welding rod, Special No. 1, used to weld a $^7/_8$-in. thick plate. The analysis of this rod was:

Silicon, %	2.60
Manganese, %	1.35
"ratio"	1.93

Although the plate flowed freely during the welding operation, the welding rod melted viscously and stubbornly. The welder was never able to complete the first layer because the weld cracked during cooling. A single layer longitudinal weld is unrestrained and is the easiest to weld; thus, the trouble would even be worse with multi-layer girth welds. This typical case showed that a "ratio" of two or less is not a suitable analysis for a weldable copper-silicon alloy rod.

It is possible that the same combination of plate and rod analysis with single-layer welding of $^3/_{16}$ in. or less thickness of plate would not crack because of the blending of the rod and plate analysis would result in a higher "ratio" of weld metal.

With "ratios" of 2.00 to 2.75, multi-layer welds will generally crack in the second pass of multi-layer welds if the welding rod or plate analysis is in this range. A typical case was a $^7/_8$-in. thick plate having the following analysis:

Silicon, %	3.05
Manganese, %	1.19
"ratio"	2.69

The weld pool adjacent to the plate was viscous and stubborn and appeared like sand during the welding operation but the welding rod with unknown analysis melted with good fluidity. Only expert welders can weld such analysis of plate. Such a "ratio" can cause hot shortness in a multi-layer weld and is therefore undesirable for thicknesses of plate over $^1/_4$ in. for which multi-layer welding is generally necessary. A single-layer restrained weld such as girth weld will generally crack, particularly when completing the weld, when this "ratio" is used.

With "ratios" of over 3.10 for the plate or welding-rod analyses, the weld pool will "melt freely" and multi-layer or restrained welds can be made without cracking.

Following are two typical and separate cases:

	No. 1 plate	*No. 2 rod*
Copper, %	96.10	95.40
Silicon, %	2.84	3.29
Manganese, %	0.89	1.07
Iron, %	0.11	0.10
Ratio Si/Mn	3.19	3.08

In both cases, with normal Fe content, the melted plate in case of No. 1, and the weld pool in the case of No. 2, had better than average fluidity.

Following is a history of the minimum "ratios" for the copper-silicon welding-rod analyses:

Year	*1935*	*1938*	*1948*
Min Si, %	2.75	3.15	3.20
Max Mn, %	1.25	0.90	0.95
Min "ratio"	2.20	3.50	3.37

From 1938 to date, welding tests on hundreds of different welding-rod analyses showed that the specified minimum "ratios" prevented cracking in multi-layer welds. It also has been ideal for full fusion single-layer welds. Occasionally some heats did not quite meet these limits and tests on these indicated that the minimum fluidity desired by welders were those with a "ratio" of 3.3.

In order to get a higher "ratio" it is necessary to raise the Si, lower the Mn, or both. This was the next step in the investigation.

With "ratios" of over 4.20 and with normal Fe contents, tests showed that free-bend specimens in heavy gages could be bent 180° without the weld cracking, which ordinarily is unusual in heavy gages. Following is the analysis of such a welding rod:

Silicon, %	3.43
Manganese, %	0.78
Iron, %	0.18
"ratio"	4.46

When this rod (heat no. 246) was used in oxyacetylene welding a $^7/_8$-in. thick plate, the ASME free-bend specimen with the weld in the middle, bent a full 180° without any cracking even though the iron content was a little above normal. This certainly is a most desirable feature for a weld.

The real proof was to use high "ratios" of plate and rod analyses in actual pressure vessels and put such vessels in service. Table 3 gives data on some analyses of plates and welding rods with "ratios" as high as 8.2 which were successfully used in pressure vessels.

Improved methods of manufacture to eliminate completely oxide inclusions in welding rods was established after some of the above experimental work was finished.

The oxides could be silicon oxide with a melting point of 1710° C and/or cupious oxide with a melting point of 1235° C. Since the copper-silicon melts at approximately 1019° C, the including of these two oxides with their higher melting points in the rod would leave unmelted inclusions in the weld metal.

Table 3—Typical Welding-Rod and Plate Analysis with "Ratios" Over 4.20

Heat no.	*Date*	*Chemical analysis, %* Si	Fe	Mn	*Ratio, Si/Mn*	*Fluidity*
			Welding rod			
UM-2	1945	3.82	0.51	0.75	5.1	Very good, note high Fe and Si contents
UM-3	1945	3.80	0.62	0.62	6.1	
UM-4	1945	3.90	0.60	0.76	5.1	
134	1939	3.60	0.14	0.73	4.9	Very good, all used successfully for welding large pressure vessels, note high Si contents
403	1943	3.84	0.18	0.57	6.7	
460	1943	3.80	0.34	0.52	7.3	
524	1943	3.75	0.18	0.65	5.8	
670	1946	3.97	0.16	0.62	6.4	
405	1950	3.98	0.17	0.49	8.1	
			Plate			
—	1934	3.28	0.45	0.40	8.2	Very good, note high Fe and low Mn contents
4	1951	3.70	0.03	0.75	4.9	Very good, used successfully for 84 and 108-in. diam storage tanks for liquid nitrogen (−320° F) and oxygen (−300° F) service, note high Si contents
18	1951	3.70	0.04	0.74	5.0	
29	1951	3.70	0.04	0.65	6.2	
34	1952	3.75	0.07	0.64	5.9	
18	1952	3.80	0.02	0.69	5.5	
6	1952	3.74	0.02	0.76	4.9	

Therefore to be sure that the analysis and not the process was the determining factor on fluidity, three special heats of welding rod were made in 1940 with the following rod analyses:

Heat no.	Analysis, % Si	Fe	Mn	α	"Ratio"
Special no. 1	2.60	0.06	1.35	2.34	1.92
Special no. 2	3.03	0.06	0.74	2.92	4.10
Special no. 3	3.31	0.15	0.77	3.30	4.20

Welders were given these three varying analyses of welding rod to weld the same $^{7}/_{8}$-in. thick plate to first determine fluidity of the rods when melted by oxyacetylene welding. The welders' reaction to Special no. 1 rod with a "ratio" of 1.92 was that "this was just like some of the old analyses with very poor fluidity (low "ratio")." The welders reported that both Special no. 2 and 3 rods with a "ratio" of over four had excellent fluidity.

Welds using these three rods were then completed in three identical $^{7}/_{8}$-in. thick plates. Two 0.505-in. diam all-weld specimens were taken longitudinally down the weld for each of the three analyses.

The results were as follows:

Heat no.	Tensile strength, psi
Special no. 1	49,150 and 49,400
Special no. 2	51,250 and 51,800
Special no. 3	53,000 and 54,000

It is to be noted that the tensile strength of the weld for No. 1 was below the 50,000 psi required by the ASME Code. This is because α was 2.34 or below the required 2.82. This rod did not flow freely so it failed on two counts—minimum tensile strength and minimum fluidity.

This finally proved that "ratio" and not the mill process determined fluidity and weldability.

All of these tests proved that high "ratios" are necessary for good fluidity. The best way to increase the "ratio" is to increase the Si content. The next question to answer is: "What is the maximum permissible Si content?"

Effect of High Silicon

Prior to 1935, the Si content range was 2.75-3.25% in rod and plate. Trouble was being experienced in obtaining the 50,000-psi minimum welded tensile strength required by the ASME Code with fractures in plate or weld. In 1935, the five experimental $^{7}/_{8}$-in. thick plates were processed exactly the same not only to determine fluidity but the effect of Si on tensile strength. A summary of the welded tensile-test results of Plates AB1 to 4 incl. with fractures in the plate are given in Table 2.

Comparing plates AB1 and 2 with almost identical Mn content, also plates AB3 and 4 with almost identical Mn content, it appeared that for every 0.10% increase in Si content there was an approximate increase of 1000 psi in the welded plate strength. This was the first clue that increasing the Si content increased the weld tensile strength but how high the Si could be was not known.

Table 2 states that plate AB5 with 4.09% Si could not be welded. Plate AB5 was cut in two equal pieces and one-half annealed at 575° C and a tensile test made. This half was beveled and oxyacetylene welded the same as the other four plates. The 575° C annealed plate cracked adjacent to the weld and in the weld. Table 4 shows that the base-metal tensile strength was over 65,000 psi and the yield strength was over 30,000 psi. Past experience had already shown that with such strengths, cracking troubles in the plate can be expected. Therefore, the other half was annealed at a higher or 700° C temperature to reduce the tensile and yield strengths; the results are also given in Table 4.

The second half of AB5 was similarly beveled and oxyacetylene welded with the same welding rod used for the first half. The first layer was welded but only with difficulty. In attempting to make the second layer, the first layer cracked.

It is to be noted from Table 2 that experimental plate AB1 with practically the same Mn and Fe contents and the same thickness but with an Si content of 3.54% was successfully welded. This proved that with other elements the same but with Si raised from 3.54 to 4.09%, there was trouble, therefore, 4.09% Si is too high for successful welding. The exact minimum Si limit must therefore be between these two figures for plate and probably rod. To determine this, the Si content of the welding rod was gradually increased. The following is a history of this gradual increase from 1935 to 1948:

Year	Max Si, %
1935	3.25
1938	3.50
1941	3.60
1948	3.85

The new or higher Si content was tested by making all-weld tensile tests of the weld each time before proceeding with the next higher figure. Table 5 shows typical tensile strengths on weld metal starting from the old lowest Si content to the present highest Si contents.

Paralleling this investigation of tensile tests on welds with higher and higher Si contents in the welding rod, was the actual usage in large ASME pressure vessels of such rods. Table 3 not only lists some of these rods but also plates. It is to be noted that welding rod heats no. 670 in 1946 and no. 405 in 1950 had Si contents of 3.97 and 3.98% and that the average tensile strength of heat no. 405 as all-weld metal was 61,300 psi, a high figure for this alloy. In 1935, it was a struggle to get all-weld metal strengths over the required 50,000 psi minimum. The 1946 and 1950 tests substantiated the "formula" which states that the higher the Si, the higher the tensile strength.

Paralleling this investigation on welding rod analysis, was a similar investigation on increasing Si contents for plate. In 1951, the mill rolled two $^{7}/_{8}$-in. thick x 140.5-in. disks for 125-in. diam heads. The mill reported Si contents of 3.79 and 3.81% for each and a Mn content of 1.00% for both. The Si contents were rechecked and found to be 3.82 and 3.85%. Because of the urgency of the pressure vessel for which these heads were intended, it was decided to go ahead but first make welding tests. The highest Si rod available then was one with 3.65%; so, it was used to make a complete ASME Procedure Qualification Test with impact specimens using manhole cutouts from both heads. Table 6 gives the results of this test which easily passed the ASME requirement. It is to be noted (1) that for the weld and adjacent to weld, impact values were 2 to 3 times the required 15 ft-lb; (2) that the root and face bends (with welds in the middle) bent the full required amount with no cracking; (3) that 3 out of 4 of the tensile tests were over 60,000 psi.

Table 4—Base-Metal Tensile Tests — Plate AB-5

Annealed at	Type of tensile specimen	Tensile strength, psi	Yield strength, psi	Elongation in 2 in., %
(575° C) 1017° F	Reduced-section	66,200	32,400	23.4
(700° C) 1292° F	Reduced-section	58,800	19,700	38.8
(700° C) 1292° F	0.505 in. diam	57,800		44.0

This was the final test on high Si in plate.

As a result, a new A8 analysis was added to the 1955 issue of ASTM Specifications B96 and B97 for sheet and plate with Si made 3.15 to 3.8%.

Tests have proved that to make the tensile strength of the all-weld metal the same as for the welded plate, it is required that the Si content in the welding rod be 0.15–0.25% higher than for plate. Three typical test data are shown in Table 7.

It actually is α that determines the tensile strength, but Si increases in direct proportion to the α increase. Therefore, if the maximum Si content for plate is 3.8% then for welding rod it should be 4.0%.

The present copper-silicon welding-rod specification[1] does have a maximum Si content of 4.00 or 0.2% higher than for the A8 plate specification. This 4.0% is the limit as the above test data proved that 4.09% Si was too high but 3.98% was satisfactory.

The "formula" states that the lower the Mn content, the higher the tensile strength. Fluidity data shows that the lower the Mn content, the higher the fluidity of the weld pool. Therefore, there is every advantage in making the Mn content as low as possible. The next question to answer was: "What is the lowest permissible Mn content?"

Effect of Low Manganese

In 1931, a 3/8-in. thick plate with no Mn was oxyacetylene welded. The approximate analysis was:

Silicon, %	Between 2.00 and 3.00
Iron, %	Between 0.30 and 0.80
Manganese	None
Tin	None
Zinc	None

The first layer was welded successfully. The second layer cracked no matter what welding technique was tried. In other words, as soon as a restraint was put on the weld, the preceding weld cracked.

In 1932, a 3/8-in. thick plate with no Mn and high Si was oxyacetylene welded. Following is the analysis and tensile strength of the plate:

Si, %	3.73
Fe %	0.07
Mn	None or trace
Tin, %	0.59
Tensile strength, psi	61,700

The joint was a 60-deg included angle, double-bevel with backing strip. Following are the results after welding:

1. Full-section welded tensile—45,200 psi, broke in base metal in center punch marks—sharp break.

2. Full-section welded tensile—48,900 psi, broke in base metal where backing strip was carbon-arc welded on—sharp break.

In 1934, a 3/8-in. thick plate with Mn lower than the usual 0.75% minimum and having the following analysis:

Si, %	3.28
Mn, %	0.40
Fe, %	0.45

was welded without difficulty with the following results:

Full-section welded tensile strength 62,000 psi, broke in base metal.

Through 1938, the Mn content range of the welding rod had been 0.75 to 1.25% with the average 1.00%. Fluidity and tensile tests showed the advantage of lowering the Mn content. Therefore, through 1939 and 1940, the average Mn content was made 0.75% with an occasional trial heat at 0.65%. Reports on the latter showed still greater ease in welding; so, in 1940 the maximum Mn content was lowered to 0.90%.

In 1941, several heats with Mn as low as 0.55% were made. One of these heats with 0.48% Mn is reported in Table 5. These welding rods were so superior to those with the higher Mn contents that in 1941 the minimum Mn content was set at 0.55%. The history on hundreds of heats made during 1942–44 with the average Mn content 0.65% and occasionally some as low as 0.50% showed all of the welding advantages and no disadvantage in making the Mn content low but how low was not definitely known.

In 1945, a fillet weld was made with a welding rod having the following chemical analysis: Si, 1.60% and Mn, 0.25%. There was no trouble welding this low Si and low Mn rod. This is alloy R Cu Si-B in AWS welding rod specification A5.7. It is a weldable alloy although the tensile strength is low as compared with the Alloy R Cu Si-A because the Si is low. This welding-rod alloy is the same as the plate alloy in ASTM B97, Alloy B14 with minimum Mn 0.20%. The plate alloys with the higher Si content but with the minimum Mn set at 0.20% are alloy A8 in ASTM specifications B96 and B98.

Summarizing, the 1931 and 1932 tests did, however, show that, with no Mn, the alloy is both hot short (cracks during welding) and cold short (coupon breaks on punch marks or where backing strip was welded on). The Mn evidently acts as a deoxidizer and some, beyond a trace, is necessary. Since ASTM plate specifications A8 and B96 and B97 sets the minimum Mn content at 0.20%, the same can apply to welding-rod specifications.

If this is true, perhaps adding phosphorous would have the same effect. The following test data prove this point.

Table 5—Effect of Increasing Silicon on Weld Tensile Strength

Heat no.	Billet or rod analysis, % Si	Fe	Mn	α	Average tensile strength, psi
Oxyacetylene Welded					
0.505-in. diam all-weld specimens					
SP-1	2.60	0.06	1.35	2.34	49,250
SA-1	2.99	0.10	1.24	2.80	51,700
SA-3	3.00	0.05	0.97	2.82	50,200
N1351	3.38	0.07	1.06	3.20	53,300
257	3.38	0.19	0.48	3.50	54,000
...	3.46	0.16	0.74	3.48	54,400
124	3.54	0.14	0.66	3.05	54,200
358*	3.59	0.06	0.68	3.49	53,900
3/8-in. thick reduced tensile (with fractures in the weld)					
N1402	3.18	0.07	0.98	3.02	52,000
97	3.28	0.09	1.02	3.14	52,900
153*	3.50	0.15	0.65	3.52	53,500
02600	3.54	0.14	0.66	3.55	53,900
360*	3.63	0.19	0.73	3.68	54,300
Carbon-Arc Welded					
0.505-in. diam. all-weld specimens					
99*	3.21	0.11	1.02	3.10	53,700
340*	3.54	0.15	0.76	3.54	56,700
405	3.98	0.17	0.49	4.07	61,300
1/2-in. thick reduced tensile (with fractures in the weld)					
391*	3.19	0.16	0.60	3.24	54,900
336*	3.51	0.19	0.67	3.58	57,900
Inert-Gas Welded					
Reduced tensile with fractures in weld					
	3.52	0.22	0.63	3.63	59,200
673	3.65	0.04	0.66	3.54	60,500

The above analyses are on the rod except those marked with a *.

Table 6—ASME Procedure Qualification Test for High-Silicon Plates with Inert-Arc Welding

	Chemical analysis, %		
	3/8-in. thick plate 5	3/8-in. thick plate 11	Rod 673
Copper	94.99	95.09	95.42
Zinc	0.07	0.00	
Lead	0.00	0.00	
Tin	0.00	0.00	
Iron	0.07	0.07	0.04
Silicon	3.79	3.81	3.65
	3.82 recheck	3.85 recheck	
Manganese	1.00	1.00	0.66
Nickel	0.05	0.03	
Ratio Si/Mn	3.80 avg	3.83 avg	5.52

Test Results, Plate No. 5 Using Welding Rod No. 673

Specimen no.	Type of specimen	Results
H73	Free bend	87% elongation in 0.03 in.
H76	Free bend	71.5% elongation in 0.25 in.
H72	Root bend	No cracks
H75	Root bend	No cracks
H74	Face bend	No cracks
H77	Face bend	No cracks
H78	Reduced section	60,000 psi fractured in base metal
H71	Reduced section	56,250 psi fractured in fusion zone
H81	Impact 10 x 10 mm	44 ft-lb at −320° F, notch in center of weld
H84	Impact 10 x 10 mm	33 ft-lb at −320° F, notch in center of weld
H86	Impact 10 x 10 mm	44 ft-lb at −320° F, notch in center of weld

Test Results, Plate No. 11 Using Welding Rod No. 673

J16	Free bend	61% elongation in 0.22 in.
J19	Free bend	58% elongation in 0.25 in.
J15	Root bend	No cracks
J18	Root bend	No cracks
J17	Face bend	No cracks
J20	Face bend	No cracks
J14	Reduced section	60,600 psi fractured in weld metal
J21	Reduced section	60,800 psi fractured in weld metal
J24	10 x 10 mm impact	29 ft-lb at −320° F, notch in center of weld
J27	10 x 10 mm impact	32 ft-lb at −320° F, notch in center of weld
J29	10 x 10 mm impact	31 ft-lb at −320° F, notch in center of weld
J22	10 x 10 mm impact	43 ft-lb at −320° F, notch in fusion zone
J26	10 x 10 mm impact	54 ft-lb at −320° F, notch in fusion zone
J28	10 x 10 mm impact	53 ft-lb at −320° F, notch in fusion zone

Effect of Phosphorus

It is well known fact that phosphorus acts as a deoxidizer for copper but is this true for a copper-silicon alloy?

In 1936, a 3/8-in. thick plate, with no Mn, but with a trace of phosphorus having the following analysis and tensile strength, was welded:

Si, %	Between 2.50 and 2.75
Fe, %	Between 0.10 and 0.15
Cu	Remainder
Mn	None
P, %	about 0.02
Tensile strength, psi	57,000

The results were as follows:

Four reduced-section welded tension specimens—between 42,400 and 48,150 psi.

The tensile strengths were about what would be expected for this low Si content. The main point, however, is that with no Mn but with phosphorous added as a deoxidizer, the alloy was weldable. Therefore, either Mn or phosphorus can be in the rod composition for weldability.

Effect of High Iron

In the early experimental work, Fe was not considered in the study because the normal rod composition had a low Fe percentage impurity between 0.04–0.11%. Further test work proved that Fe was a definite factor.

It was the "formula" that first showed the effect of Fe. It is to be noted from the "formula" that Fe increases the tensile strength 1.25 times as fast as Si. In 1943, two heats with higher than normal Fe contents were noticed; so, these were "tagged" for welding-rod tests. In order to be sure that the original billet analyses were correct, analyses were made of the actual rods and the weld. All three analyses and the tensile-test results of the fillet carbon-arc welds are given in Table 8.

This was the first time that an ultimate tensile strength of 60,000 psi had been definitely passed for all-weld metal. These welds were made by an inexperienced welder so it was not welding experience but Fe in the rod composition that caused the high tensile strength. It is to be noted that the Fe content of the rod and weld are practically the same and so did not change during welding.

In 1944 special heats were made and Fe was purposely added to result in approximately 0.50, 0.75 and 1.25% Fe. Table 9 gives the test results of welds made in 1945.

Considerable difficulty was experienced in welding the rods with approximately 0.75 and 1.25% Fe. It is to be noted that the tensile strengths instead of increasing dropped with Fe over 0.50%, and very sharply over 0.75%. These can be more easily seen in Figs. 1 and 2. This trouble can be explained by the fact that the original Fe does not seem to stay in the weld metal. It was very difficult to check the Fe content of the weld when the rod had approximately 1.25% Fe because some of the Fe came out of

Table 7—Comparison of Analysis and Tensile Strengths of Welded Plates and Welds

Analysis of	Weld	Heat no.	Chemical analysis, % Si	Fe	Mn	α	Average tensile strength, psi
3/8-in. thick plate	Inert arc	1950	3.37	0.07	0.71	3.18	56,700*
Welding rod	Oxyacet.	340	3.54	0.15	0.76	3.54	56,750†
3/8-in. thick plate	Oxyacet.	N1271	3.20	0.18	1.02	3.18	55,100*
Welding rod	Oxyacet.	335	3.46	0.16	0.72	3.18	54,300‡
3/8-in. thick plate	Oxyacet.	M9609	3.07	0.08	1.04	2.91	52,600*
Welding rod	Oxyacet.	97	3.28	0.09	1.28	3.14	52,300‡

* Reduced section specimens with fracture in plate.
† 0.505-in. diam all-weld specimen.
‡ Reduced section specimens with fracture in middle of weld.

Table 8—The Effect of Medium Iron Content on Weld Tensile Strength

Heat no.	Of:	Analyses, % Si	Fe	Mn	α	Tensile strength, psi*
405	Billet	3.78	0.25	0.54		
	Rod	3.59	0.17	0.59	3.65	
	Weld	Unknown	0.17	0.49		61,500, 61,100
408	Billet	3.54	0.41	0.48		
	Rod	3.50	0.26	0.56	3.68	
	Weld	Unknown	0.25	0.50		59,200, 61,300

* Test specimens were 0.505-in. diam carbon-arc all-weld metal from a fillet weld.

solution and was free. This was proved by the fact that a magnet could pick up free Fe from the weld metal. Table 9 shows that the billet Fe content is not the same as the rod, indicating that the Fe content is not uniform throughout the billet.

That this drop in tensile strength is due to high Fe, can be proved by comparing the Si and Fe contents given at the bottom of Figs. 1 and 2. For instance in Fig. 1 compare the following test data:

Si, %	Fe, %	α	Tensile strength, psi
3.30	1.27	4.86	38,000 42,800
3.31	0.15	3.30	54,000 53,000

In this case with the Si content the same, the 1.27% Fe rod had a much lower tensile strength.

For instance in Fig. 2 compare the following test data:

Si, %	Fe, %	α	Tensile strength, psi
3.23	1.27	4.78	51,300 38,200
3.19	0.16	3.24	55,000 54,800

Again the 1.27% Fe caused a sharp drop in the tensile strength of one specimen with like Si contents.

In the case of both Figs. 1 and 2, the highest tensile strength is with an Fe content of 0.55%. The Fe content should therefore be a little less than 0.55%. The welding specifications[3] have the maximum Fe content of 0.50%; therefore, this is satisfactory.

Effect of Zinc, Tin, Nickel and Lead

The discussion so far has dealt with the effect of Si, Mn and Fe on weldability and strength. The present welding-rod specifications[1] also permit the following elements to be present:

Zinc, % max	*1.5
Tin, % max	*1.5
Nickel	Not given
Lead, % max	0.05

* One or more of these elements may be present within the limits specified.

The following are analyses that have been tested in copper-silicon welding-rod analysis and found not to affect adversely weldability or strength:

Zinc—1.12% (heat no. 97), 2.88% (heat no. 288), 2.12% (heat no. 201);

Tin—only four heats of welding rod were known to have tin and these had 0.03, 0.04, 0.07 and 0.59%;

Nickel—0.15% (heat no. 358), 0.35% (heat no. 200);

Lead—0.05% maximum.

Skilled welders can tell instantly when this alloy has a lead content of 0.10%. This amount of lead causes trouble during welding and results in "pimply" looking weld metal; however, 0.05% maximum has proved satisfactory.

In AWS-A5.7 welding-rod specification, it is to be noted that tin is specified as 1.00 to 1.20% maximum for the brass and bronze rods and 4.0 to 6.0% for the copper-nickel rod so these percentages must be satisfactory.

The above limits for zinc, tin, lead and nickel have been acceptable to the mills producing this alloy in rod and plate. This, together with such tests as have been made, indicates that the present copper-silicon welding-rod[1] maximums are satisfactory for these four elements.

Effect of Aluminum

Tests were run in 1935 to determine the effect of aluminum on the weldability of the copper-silicon alloy. Increasing percentages of aluminum were added to the welding rod and tested by welding a ½-in. thick plate. The results are given in Table 10.

The alloys with 0.039 and 0.053% aluminum were of poorer weld quality than the one with 0.025% aluminum but the latter was not satisfactory. Since 0.007% aluminum can be produced commercially, the limit can be set at 0.010% maximum aluminum and will produce an alloy that results in sound welds.

Summary

This research on the copper-silicon welding rod has introduced to the welding industry two new concepts that make it possible to select the correct chemical analysis of the welding rod by mathematics.

The first concept is: the ultimate tensile strength of the copper-silicon weld metal can be determined by means of a mathematical formula. The "formula"[2] for this particular four-element alloy is:

$$\text{Tensile strength} = K_1 + K_2\alpha$$

where

$$\alpha = \%\text{Si} + (\%\text{Fe} \times 1.25) - (\%\text{Mn} \times 0.25)$$

K_1 and K_2 = constants for each welding procedure.

K_1 = value obtained when $\alpha = 0$.

K_2 = value obtained from slope of line.

When the tensile strengths from tests are plotted versus α, the result is a straight-line band within the limits of weldability, with the width of the band approximately 1000 psi. The accuracy is therefore plus or minus 1% from the average. The upper line is the maximum and the lower line the minimum value. From this, the constants K_1 and K_2 can be calculated; however, it generally is easier to use the plotted results Figs. 1 and 2 to determine tensile

Table 9—Effect of High Iron Content on Weld Tensile Strength

Weld	Heat no.	Rod analysis, % Si	Fe	Mn	α	Tensile strength, psi
Carbon arc	Special 7	3.72	0.55	0.56	4.27	63,900, 62,600
Carbon arc	Special 5	3.65	0.74	0.60	4.43	59,200, 61,300
Oxyacet.	Special 5	3.65	0.74	0.60	4.43	60,400,
Oxyacet.	Special 2	3.65	0.77	0.54	4.48	53,500, 58,300
Carbon-arc	55631	3.23	1.27	0.52	4.78	51,300, 38,200
Oxyacet.	55632	3.30	1.27	0.52	4.86	42,800, 38,200
Oxyacet.	55633	3.23	1.31	0.51	4.84	51,600*

* This test specimen was reduced-section tensile with fracture in middle of weld, all others were 0.505 in. diam machined from fillet welds.

strength. Using the lower line, it was shown that, for the required minimum ASME weld tensile strength of 50,000 psi, the minimum $\alpha = 2.82$.

The second concept is that weldability of this alloy is determined to a great extent by the fluidity of the weld pool. Fluidity is determined by the ratio of Si/Mn. In order to be able to use the copper-silicon welding rod for multilayer welding, test data show that the minimum "ratio" of Si/Mn should be 3.3. Actually if the "ratio" is over 4.0, the weld ductility is greater. "Ratios" as high as 8.2 have been successfully used.

This research shows the maximum limits of silicon 4.0%, aluminum 0.01%, lead 0.05%, zinc 1.5%, and tin 1.5% in the present copper-silicon rod specifications[1] are satisfactory. However, the present limits of Mn 1.5% maximum and Si 2.8% minimum are not satisfactory. The correct values will be determined mathematically in the following discussion.

Selection of Welding-Rod Analysis by Mathematics

The "formula" and the minimum "ratio" determine the minimum Si and the maximum Mn contents. Present welding-rod specifications[1] have set the minimum Si at 2.8% and zinc, tin and Mn at 1.5% for one or more of these elements. In the usual copper-silicon alloy welding-rod analysis, zinc and tin are very low so Mn could be 1.5%.

Iron generally occurs as an impurity in this alloy and a check of numerous heats indicates that the minimum is generally about 0.04%. Since the minimum "ratio" should be 3.3 and the minimum Si in the welding-rod specifications[1] is 2.8, then the maximum Mn would be 2.8/3.3 or 0.85%. Substituting these figures in

$$\alpha = \%\text{Si} + (\%\text{Fe} \times 1.25) - (\%\text{Mn} \times 0.25)$$

$$\alpha = 2.8 + (0.04 \times 1.25) - (0.85 \times 0.25)$$

$$\alpha = 2.64$$

Table 10—The Effect of Aluminum on Weldability

Heat no.	*Aluminum, %*	*Weldability*	*Appearance of weld*
—	None	OK	Thin slag coating
—	0.007	OK	Smooth, clean and proper color
EA1	0.025	NG	Slightly rough, porous and dark color, heavy slag coating
EA2	0.039	NG	
EA3	0.053	NG	

Since this figure should be 2.82 minimum, either the Si has to be increased or the Mn decreased, or both. Following is a table that lists what the Mn content will be with different Si contents with α at 2.82 and Fe at 0.04%:

Si, %	*Mn, %*	*"Ratio"*
2.80	0.12	23.2
2.90	0.52	5.67
3.00	0.92	3.26
3.10	1.32	2.35
3.15	1.50	2.1

Those with a "ratio" below the desired 3.3 are unsatisfactory because of fluidity.

Following is a table that lists what the Mn content will be for different Si contents with the "ratio" held at 3.30:

Si, %	*Mn, %*	*α (with 0.04% Fe)*
2.80	0.85	2.64
2.90	0.88	2.73
3.00	*0.91*	*2.82*
3.10	0.94	2.91
3.20	0.97	3.01

Therefore, mathematically the Si should not be below 3.0% and the Mn not higher than 0.9% in order to meet both the minimum α of 2.82 and the minimum "ratio" of 3.3.

Recommendation

It is therefore recommended that two revisions be made in the present copper-silicon alloy welding specifications[1] for welding rod R Cu Si-A to bring it to an ideal welding rod. These are: (1) make the Mn content as a range of 0.2–0.9%, and (2) change the present Si range from 2.8 to 4.0 to 3.0–4.0%.

Acknowledgment

The author wishes to thank the various branches of The American Brass Co. and the laboratory of Electro-Metallurgical Co., Division of Union Carbide Corp. at Niagara Falls, N. Y. for their cooperation. Figures 1 and 2 and some of the test data were originally published by the ASTM[2] but are repeated here to make the paper complete in itself.

Bibliography

1. AWS-A5.7, ASME SB-259, ASTM B-259 copper-silicon rod R Cu Si-A.
2. Bohn, G. H., "A Mathematical Formula for the Calculation of the Tensile Strength of Copper-Silicon-Manganese-Iron Alloy," *ASTM Proceedings*, **55**, (1955).
3. ASME Boiler and Pressure Vessel Code, Section IX, Part B, Welding Qualifications.
4. AWS Welding Handbook, Third Edition, Copper and Copper Alloys, p. 1346.
5. *Ibid.*, Third Edition, p. 22.

RESEARCH NEWS

(*Continued from page 527-s*)

veloped less than 15 foot-pounds V-notch Charpy impact energy at room temperature even with the best commercial titanium wire. Low alloy alpha-beta weld deposits produced by depositing unalloyed titanium filler in alloy base metals or by depositing alloy filler in unalloyed base metal developed appreciably greater toughness than unalloyed weld deposits. Matching alloy filler and base metal compositions developed little or no toughness in either the weld or heat-affected base metal. Bead-on-plate notch-bar impact test specimens were used for evaluation of relative notch toughness.

An Investigation of the Mechanical Properties of Metal-Arc Welded Ti—6% Al—4% V. D. M. Daley, Jr., and C. E. Hartbower, Watertown Arsenal, U. S. Army. Sept. 1956. 18 pages. (Order PB 131114 from OTS, U. S. Department of Commerce, Washington 25, D. C., 50 cents.) The Ti-6Al-4V alloy is described as one of the most promising of the new commercial alloys. As a base metal it has shown good yield strength and satisfactory notch-toughness, in the as-rolled annealed condition. The tests described in this volume evaluated the tensile and notch-bar impact properties of a weld deposit of the alloy prepared by the inert-gas-shielded tungsten-arc process using a single heat of Ti-Al-V as both filler and base material. Additional tests were made of

(*Continued on page 552-s*)

STRESSES IN A PRESSURE VESSEL WITH CIRCUMFERENTIAL RING STIFFENERS

Paper evaluates the stresses in the shell of a pressure vessel, operating under internal pressure, induced by circumferential stiffening rings

BY F. W. CATUDAL AND R. W. SCHNEIDER

ABSTRACT. Most formulas found in pressure-vessel design codes contain factors which compensate, in a very approximate way, for secondary stresses. These factors are often called "factors of ignorance."

It is often possible to attain a more effectively balanced design pressure vessel at lower cost and with improved safety by evaluating secondary stresses through a rigorous mathematical stress analysis. This appears to be the trend in pressure-vessel design today.[1]

Obviously, this will increase engineering costs and indicates the advantage of having design charts, which will permit the rapid evaluation of secondary stresses, based on pertinent parameters.

A chart is presented for the determination of the maximum stress adjacent to a circumferential ring stiffener on a thin-wall cylindrical pressure vessel. It has been assumed that the pressure is internal, acts longitudinally as well as radially and that the ring stiffener spacing is such that the influence of one does not extend to the next.

Stresses are given in terms of *stress ratio* which is the ratio of the total stress (direct plus secondary) adjacent to the stiffener divided by the hoop stress in the unaffected portion of the shell.

Nomenclature

P = internal pressure, psi
S_1 = longitudinal stress in shell due to pressure P, psi
S_2 = membrane hoop stress in shell due to pressure P, psi
$S.R.$ = ratio of total longitudinal stress (direct plus bending) in the shell adjacent to the ring stiffener to the hoop stress in the unaffected shell, $(S_1 + S_1')/S_2$, dimensionless
S_1' = longitudinal bending stress in the shell adjacent to and caused by the ring stiffener
‡R = outside radius of shell, in.
R_* = outside radius of ring stiffener, in.
t = thickness of shell, in.
C = width of ring stiffener, in.
K = R_*/R, dimensionless
ν = Poisson's ratio
Δ = radial displacement due to imposed load, positive when representing an increase, in.
E = modulus of elasticity, psi
θ = change in slope due to imposed loads, positive when outward, radians
D = $Et^3/12(1 - \nu^2)$
λ = $\left[\frac{3(1 - \nu^2)}{R^2t^2}\right]^{1/4}$
N_0 = axial force per unit length of circumference, lb/in.
V_0 = shear force per unit length of circumference, at edge of ring, exerted by the ring stiffener on shell, lb/in.
M_0 = bending moment per unit length of circumference, at edge of ring, exerted by the ring stiffener on shell, in-lb per in.
M_X = same as M_0 except at any point x in. from the ring
x = distance along shell measured from edge of ring stiffener, in.

Introduction

Cylindrical pressure vessels operating under external pressure are frequently strengthened against collapse by means of circumferential stiffening rings welded to the shell. A shell can be stabilized against collapse by making the wall sufficiently heavy; however, in many instances it is more economical to use a thinner shell strengthened by means of circumferential ring stiffeners.

Many vessels which normally operate under external pressure conditions may, at times, operate with positive pressure in the shell. It is thus the purpose of this paper to evaluate the stresses in the shell of a pressure vessel, operating under internal pressure, induced by circumferential stiffening rings.

Normally, a stiffener of any sort is thought of as stiffening a part with a subsequent reduction in stress as compared with an identical unstiffened part. In the case under consideration ring stiffeners cause a stress in the shell, adjacent to the ring, which may be as high as 2.04 times the maximum stress (hoop) in an unstiffened shell of identical size. The stress adjacent to a ring stiffener is local and fades rapidly

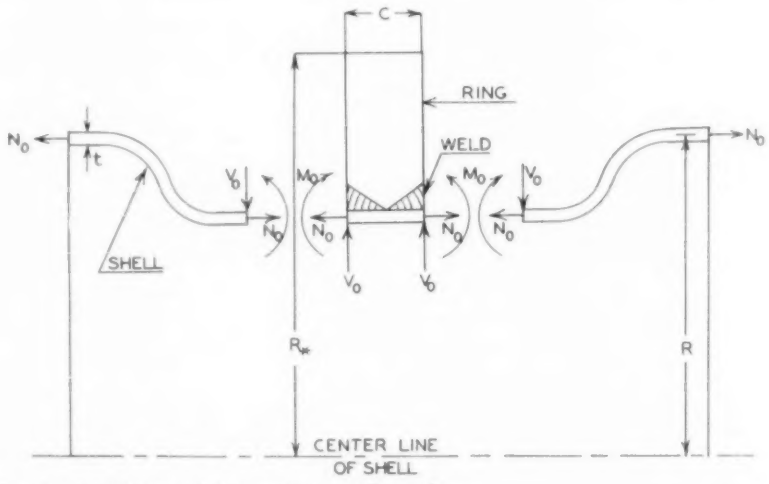


Fig. 1 Equilibrium of shell and ring stiffener forces

In the analysis R was assumed to be outside radius of shell. See nomenclature and footnote ‡

F. W. Catudal and R. W. Schneider are associated with the Travelers Indemnity Co., Engineering and Loss Control Division, Hartford, Conn.

‡ R has been taken as the outside radius of the shell, instead of mean radius, to eliminate an additional variable. For shells with a large radius to thickness ratio the affect is negligible.

with increasing distance from the ring. In no case will a ring stiffener decrease the stress below that which would occur in an unstiffened shell unless the spacing of the rings is such that the influence of one extends to the next.

A stiffening ring causes a longitudinal bending stress in the shell, adjacent to the ring, which is compressive at the outer wall and tensile at the inner wall. In addition to this bending stress there exists a longitudinal membrane (direct) stress due to the pressure acting on the closed ends of the vessel; such stress being tensile. The sum of the longitudinal direct stress and the longitudinal bending stress is maximum at the inner wall by virtue of the fact that both stresses are tensile; accordingly, this paper considers only the total stress in the shell adjacent to the ring stiffener at the inner wall.

The stresses are presented (Fig. 3) in terms of a *stress ratio* which is the ratio of the total longitudinal stress in the shell adjacent to the ring stiffener at the inner wall to the hoop stress in a simple, unstiffened shell of like size. Since the influence of a stiffener is greatest immediately adjacent to the ring, the *stress ratios* presented in Fig. 3 are for a point on the inner wall of the shell, at the intersection of the shell with the ring; they represent maximum values.

Analysis

The following brief analysis is based on the method of superposition. Figure 1 shows the loads which are applied to the shell and ring stiffener for the condition of equilibrium.

Figure 1 may be considered as a shell under edge shear (V_0), edge moment (M_0) and axial load (N_0), whereas the ring may be considered as a thick-wall cylinder under the action of edge shear (V_0), plus equal and opposite edge moments (M_0).

Figure 2 shows sections under the influence of the various types of loads with expressions for edge displacement and edge slope indicated for each.[2]

Imagine the shell and ring assembly cut as shown in Fig. 1. Since the slope of the shell adjacent to the ring is zero, Figs. 2-A and 2-B may be combined as follows:

$$\begin{bmatrix} M_0 \\ \lambda D \end{bmatrix} + \begin{bmatrix} -\dfrac{V_0}{2D\lambda^2} \end{bmatrix} = 0 \quad (1)$$

A rigid stiffener may be considered as imposing such loads as necessary to reduce the radius of a shell an amount equal to the radial displacement of an unstiffened shell due to internal pressure P. Since a ring will increase radially due to V_0, the effective radial displacement of the shell adjacent to the ring will be equal to the radial displacement of an unstiffened shell (Fig. 2-C) less the radial displacement of the ring stiffener (Fig. 2-D). Referring to Fig. 2:

$$\Delta_1 + \Delta_2 = -[\Delta_3 - \Delta_4] = -\Delta_3 + \Delta_4$$

or it may be expressed

$$\Delta_1 + \Delta_2 + \Delta_3 = \Delta_4$$

$$\frac{M_0}{2D\lambda^2} - \frac{V_0}{2D\lambda^3} = -\frac{0.85PR^2}{Et} + \frac{2V_0R}{CE}\left[\frac{R_o^2 + R^2}{R_o^2 - R^2} + 0.3\right] \quad (2)$$

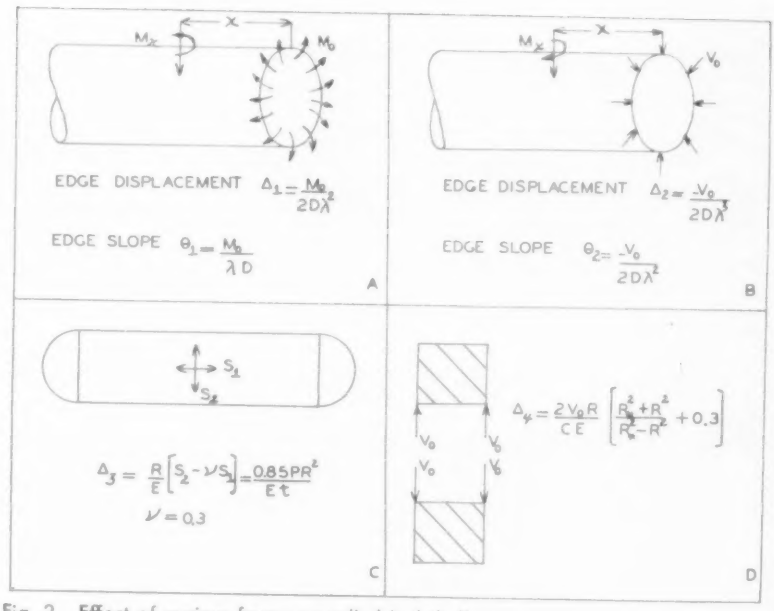


Fig. 2 Effect of various forces on cylindrical shell

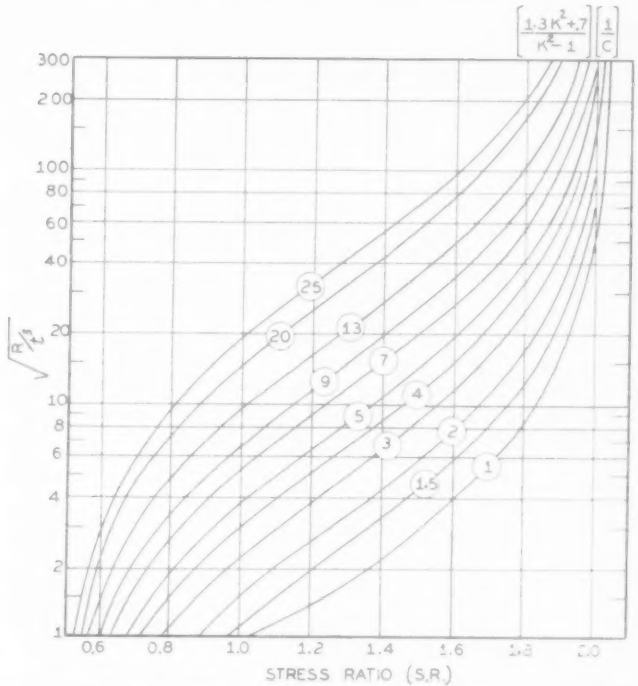


Fig. 3 Maximum *stress ratio* as a function of several parameters

Equations 1 and 2 may be solved simultaneously for M_0.

$$M_0 = \frac{(0.85PR^2)(2D\lambda^2CE)}{Et\left[CE + 8D\lambda^2R\left(\dfrac{R_o^2 + R^2}{R_o^2 - R^2} + 0.3\right)\right]} \quad (3)$$

The longitudinal bending stress in the shell immediately adjacent to the

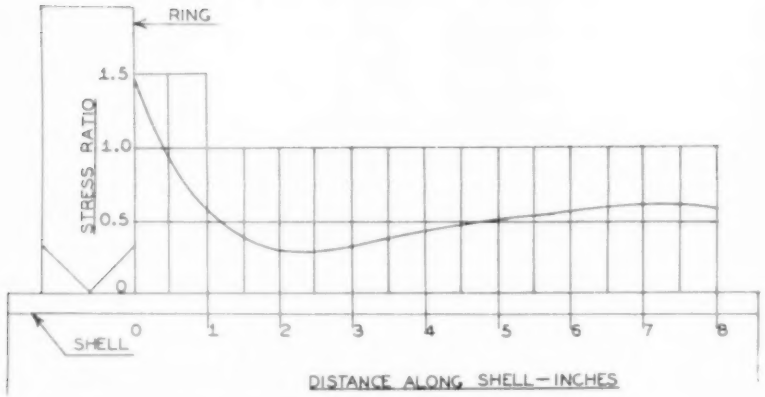


Fig. 4 Influence of distance from ring stiffener on *stress ratio*

stiffener and at the inner surface of the shell equals:

$$S_1' = \frac{6M_0}{t^2} = \frac{6(0.85PR^2)(2D\lambda^2CE)}{Et^2\left[CE + 8D\lambda^2R\left(\frac{R_e^2 + R^2}{R_e^2 - R^2} + 0.3\right)\right]} \quad (4)$$

The maximum stress occurs next to the ring and in magnitude is $S_1 + S_1'$ where $S_1 = PR/2t$. The maximum *stress ratio* is this maximum stress $(S_1 + S_1')$ divided by the hoop stress in a simple cylinder under the influence of internal pressure. Maximum *stress ratio* may be expressed:

$$\text{Max } S.R. = \frac{S_1 + S_1'}{S_2} = \frac{1}{2} + \frac{1}{S_2}\left[\frac{6(0.85PR^2)(2D\lambda^2CE)}{Et^2\left[CE + 8D\lambda^2R\left(\frac{R_e^2 + R^2}{R_e^2 - R^2} + 0.3\right)\right]}\right] \quad (5)$$

The expression is simplified by substituting the expression for D, λ, S_2 and K.

$$\text{Max } S.R. = \frac{1}{2} + \frac{10.20}{6.61 + \frac{10.288}{[R/t^2]^{1/2}}\left[\frac{1.3K^2 + 0.7}{K^2 - 1}\right]\left[\frac{1}{C}\right]} \quad (6)$$

Figure 3 represents Eq. 6 with $[R/t^2]^{1/2}$ and $[(1.3K^2 + 0.7)/(K^2 - 1)][1/C]$ as the significant parameters.

Stress Ratio vs. Distance from Ring

Equation 6 and Fig. 3 represent the maximum *stress ratio* in the shell (inner wall) at the junction of the ring stiffener with the shell. It is interesting to determine how the *stress ratio* changes away from the junction; χ being the distance from the shell-ring junction to the point in question.

Moment M_0 produces a moment M_χ at a distance χ from the junction. M_χ can be expressed:

$$M_\chi = M_0 e^{-\lambda\chi}(\cos\lambda\chi + \sin\lambda\chi) \quad (7)$$

Shear force V_0 produces a moment M_χ at a distance χ from the junction. M_χ due to V_0 can be expressed:

$$M_\chi = \tfrac{1}{\lambda} V_0 e^{-\lambda\chi}(\sin\lambda\chi) \quad (8)$$

The *stress ratio* at any distance χ from the ring stiffener may be found by adding Eqs. 7 and 8 algebraically, substituting Eq. 3 for M_0 and Eq. 1 for V_0 and then completing the solution as shown in Eqs. 4, 5 and 6.

The *stress ratio* at the inner wall of the shell at any distance χ from the edge of the ring becomes:

$$S.R. = \frac{1}{2} + \frac{10.20[e^{-\lambda\chi}(\cos\lambda\chi + \sin\lambda\chi) - 2e^{-\lambda\chi}(\sin\lambda\chi)]}{6.61 + \frac{10.288}{[R/t^2]^{1/2}}\left[\frac{1.3K^2 + 0.7}{K^2 - 1}\right]\left[\frac{1}{C}\right]} \quad (9)$$

Numerical Example

Using Fig. 3, determine the maximum stress in the vicinity of a ring stiffener on a shell of 20 in. outside radius, $^3/_{16}$-in. wall thickness under a pressure of 100 psi. The ring has an outside radius of 23 in. and is $^3/_8$ in. thick. Where is the location of maximum stress?

$$[R/t^2]^{1/2} = \left[\frac{20}{(0.1875)^2}\right]^{1/2} = 55 \quad \text{(Step 1)}$$

$$K = \frac{R_e}{R} = \frac{23}{20} = 1.15 \quad \text{(Step 2)}$$

$$\left[\frac{1.3K^2 + 0.7}{K^2 - 1}\right]\left[\frac{1}{C}\right] = \left[\frac{1.3(1.15)^2 + 0.7}{(1.15)^2 - 1}\right]\left[\frac{1}{0.375}\right] = 20 \quad \text{(Step 3)}$$

$S.R.$ from Fig. 3 = 1.49 (Step 4)

$$\text{Max Stress} = S.R.\left[\frac{PR}{t}\right] = 1.49\left[\frac{100 \times 20}{0.1875}\right] = 15{,}900 \quad \text{(Step 5)}$$

The maximum stress is 15,900 psi. The location of maximum stress is at the inner surface of the shell, immediately adjacent to the ring stiffener and is longitudinal in direction. The maximum stress, and thus the maximum *stress ratio*, always occurs at this point.

Figure 4 illustrates the variation of the *stress ratio* as a function of distance χ from the edge of the ring and was developed from Eq. 9. The maximum *stress ratio* may also be found from Eq. 9 setting χ equal to zero.

Bibliography

1. Murphy, J. J., Soderberg, C. R., Jr., and Rossheim, D. B., "Economic But Safe Pressure-Vessel Construction," Welding Research Council, Bull. No. 27 (May 1956).
2. Roark, R. J. *Formulas for Stress and Strain*, McGraw-Hill Book Co. Inc., New York, 2nd. ed., 1943, pp. 258–264.

RESEARCH NEWS

(*Continued from page 549-s*)

the notch toughness of the heat-affected zone in the alloy as produced by the same welding process. Data indicated that Ti-6Al-4V will have satisfactory properties in the as-welded condition when using matching filler and base metal. Tensile joint efficiency was approximately 100%, with an ultimate strength of 150,000 psi. Notch-toughness of deposited Ti-Al-V weld metal was acceptable at this strength level. Notch toughness of the heat-affected zone exceeded that of any other commercial alpha-beta alloy previously evaluated.

WELDING ROD CLINIC

J. Imperati and R. F. Pulver, Welding Engineers
The American Brass Company, Waterbury, Conn.

Satisfactory welding of copper bus bars

Anaconda Copper-372 Welding Rod is superior to high conductivity copper rods.

Bolted connections are the general rule in bus bar installations due to the requirements of final assembly. But there are many instances where permanent connections are made in the fabrication of individual components. When brazing is employed for this purpose, it is necessary to lap the ends of the conductors to obtain the bonded area desired.

Welded joints, however, can be used to effect savings in joint material and bus bar, at the same time adding but little to the dimensions of the conductors at the joints.

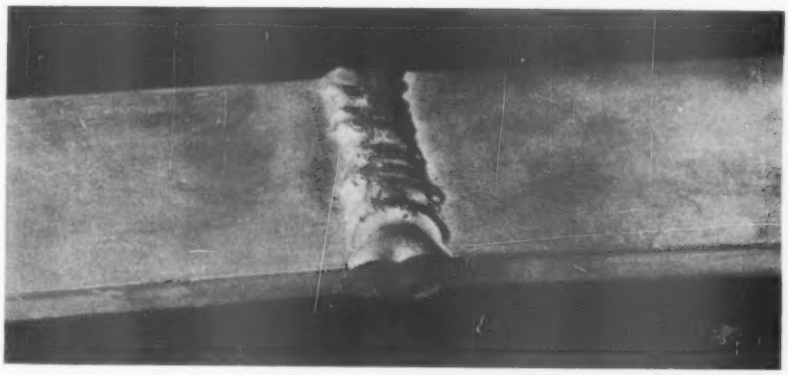
The belief that high-conductivity weld metals must be used has been a deterrent to more frequent welding. However, the volume of weld metal in a joint represents but a small percentage of the conductor, and, even if made with a low-conductivity metal, has very little effect on the over-all resistance.

Weld metal resistance negligible. This is illustrated by the figures below, which are the resistances measured on ½"-wide sections cut from a welded ¼"-thick conductor. Weld was made with Anaconda Copper-372 Welding Rod using the inert-gas tungsten-arc process.

	RESISTANCE, OHMS	
Test Length	Across the Weld	Unwelded Bar
One Meter	0.0002145	0.0002136
Two Inches	0.00001319	0.00001085

It is obvious that, when measured over lengths of several feet, the increase in resistance caused by the weld is negligible. In addition, the high heat conductivity of the adjacent base metal eliminates any tendency to produce hot spots.

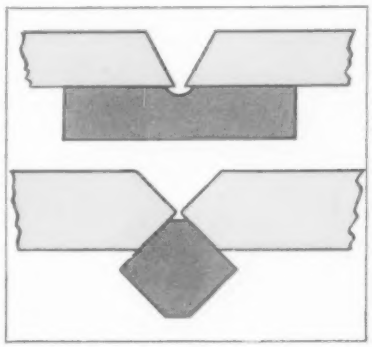
This is one reason why many of the large copper bus installations during recent years have been welded with Anaconda Copper-372 Welding Rod. Their excellent performance has shown that there is no need to forego the advantages of welded joints.



TYPICAL WELD in high-conductivity copper bus bar with Anaconda Copper-372 Rod. Weld metal is free from porosity—adds little to the thickness of the conductor at the joint.

Anaconda Copper-372 Welding Rod is a superior filler metal for this application because:

1) Dilution with the base metal and freedom from porosity counteract any tendency to develop excessive resistance. **2)** The high-conductivity coppers, which are readily available for use as filler metals, cannot be expected to deposit sound weld metal. Any electrical advantage they might have is offset by the reduction of effective cross section due to weld-metal porosity.



SINGLE-VEE GROOVE (top) is suggested when bus bars are from ⅛" thick to ¾" thick. Double-vee groove should be used for bars ¾" thick and over.

Welding methods. The inert-gas arc processes are preferred for welding copper conductors. Helium develops higher heat levels than argon and improves the flowing properties of the weld metal, and is suggested as the shielding gas for tungsten-arc welding. Argon is the usual shield in the consumable-electrode process. When thicknesses exceed ½" the joint ends should be beveled, and single-vee grooves with 90-degree included angle are the rule. Unless welding can be done from both sides, to insure fusion of the whole cross section, grooved copper backing bars should be employed on the underside of each joint. The sleeves used in tubular bus serve the same purpose. Welding must be done down hand.

For more information. Details of procedures for various thicknesses are given in Anaconda Publication B-13, "Anaconda Welding Rods and Procedures for Welding Copper and Copper Alloys." For a copy, write: The American Brass Company, Waterbury 20, Conn. In Canada: Anaconda American Brass Ltd., New Toronto, Ont.

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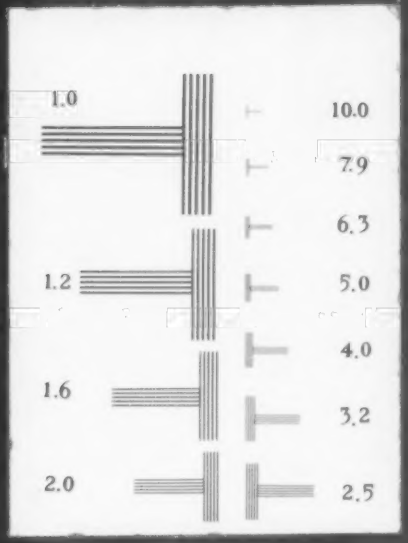

100 MILLIMETERS

INSTRUCTIONS Resolution is expressed in terms of the lines per millimeter recorded by a particular film under specified conditions. Numerals in chart indicate the number of lines per millimeter in adjacent "T-shaped" groupings.

In microfilming, it is necessary to determine the reduction ratio and multiply the number of lines in the chart by this value to find the number of lines recorded by the film. As an aid in determining the reduction ratio, the line above is 100 millimeters in length. Measuring this line in the film image and dividing the length into 100 gives the reduction ratio. Example: the line is 20 mm. long in the film image, and 100/20 = 5.

Examine "T-shaped" line groupings in the film with microscope, and note the number adjacent to finest lines recorded sharply and distinctly. Multiply this number by the reduction factor to obtain resolving power in lines per millimeter. Example: 7.9 group of lines is clearly recorded while lines in the 10.0 group are not distinctly separated. Reduction ratio is 5, and 7.9 x 5 = 39.5 lines per millimeter recorded satisfactorily. 10.0 x 5 = 50 lines per millimeter which are not recorded satisfactorily. Under the particular conditions, maximum resolution is between 39.5 and 50 lines per millimeter.

Resolution, as measured on the film, is a test of the entire photographic system, including lens, exposure, processing, and other factors. These rarely utilize maximum resolution of the film. Vibrations during exposure, lack of critical focus, and exposures yielding very dense negatives are to be avoided.